4 Scanning Techniques in Transabdominal and Intraoperative/Laparoscopic Ultrasound

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This chapter describes scanning techniques for transabdominal (TAUS), open intraoperative (IOUS), and laparoscopic (LUS) ultrasonography. The emphasis of the chapter is hepatic, biliary, and pancreatic scanning. Similarly, the discussion is based on performing a focused, not complete, diagnostic examination. The assumption is the surgeon will have a particular question in mind when performing the ultrasound examination, rather than performing a complete diagnostic examination.

The goal of this chapter is to describe techniques used to obtain optimal images of the liver, biliary tract, and pancreas. General principles, definitions, and standard imaging techniques, common to ultrasonography, are reviewed. Methods to avoid obstacles such as tissue-gas and tissue-bone interfaces and anatomic challenges are described. Techniques specific to each of the major target organs are detailed. Details not covered include ultrasound imaging physics and instrumentation, which are reviewed in Chaps. 2 and 3. Likewise, detailed specifics of liver, biliary, and pancreatic imaging are discussed in later chapters.

General Issues and Definitions

Equipment setup is determined by the type of scan, organ of interest, and the operator's position relative to the patient. Generally, TAUS scanning is done from the right side of a supine patient. The ultrasound machine and monitor are positioned on the patient's right and toward the head of the bed. This allows scanning while simultaneously changing machine settings as necessary. The bed height should be elevated to allow comfortable scanning for the ultrasonographer, either in a sitting or standing position (Fig. 4.1).

In the operating room, the machine and attached monitor are typically placed on the side of the bed opposite the surgeon (Fig. 4.2). In our case, this is most commonly on the patient's right. This has the disadvantage of requiring a third party to change machine settings when needed. If a remote monitor is available and displayed opposite the surgeon, the ultrasound machine can be placed next to the surgeon, covered with a sterile drape and settings changed by the ultrasonographer. During LUS, the use of the picture-in-picture feature is very helpful for matching external anatomic features with the corresponding ultrasound images.

Fig. 4.1 Transabdominal ultrasound setup. The examiner sits or stands on the patient's right. The ultrasound controls and monitor sit to the right of the patient's head to allow easy use and viewing

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Fig. 4.2 Intraoperative ultrasound setup. The ultrasound machine and monitor are positioned to the patient's right. The operating surgeon stands on the patient's left. If the surgeon is positioned to the patient's right, the machine is on the opposite side of the table

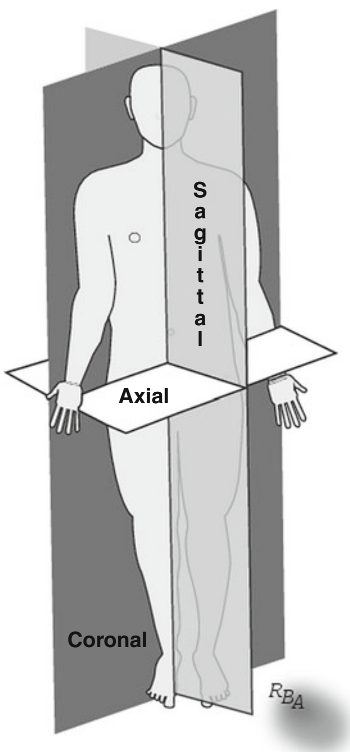

Fig. 4.3 Standard scanning planes for transabdominal ultrasound. Longitudinal planes include the sagittal and coronal planes. The single transverse plane is termed axial

Terminology and Image Display

A common terminology and display protocol are essential to allow clear interpretation of images and a reference standard for displaying static images. There are two primary imaging planes, longitudinal and transverse (Fig. 4.3). The longitudinal plane for TAUS is the long axis of the body; for IOUS or LUS, it is the long axis of the organ. Longitudinal planes include a sagittal view, when the transducer is oriented anterior to posterior, or coronal, when oriented side to side. The transverse plane gives a cross-sectional image similar to the familiar axial image seen on computed tomography (CT).

Image orientation and annotation are critical for clear communication of ultrasound images. Image orientation is standardized. When scanning in the longitudinal plane, the direction of the patient's head is oriented on the left side of the monitor screen (Fig. 4.4a). Scans done in the transverse plane are oriented such that the left side of the monitor image corresponds to the right side of the patient (Fig. 4.4b). Thus, when beginning a new scan, insure the transducer and monitor orientation are in alignment. Annotation should include the patient's name, medical record number, date of the examination, and the plane of the image.

Image acquisition consists of several important steps to obtain interpretable images: coupling, transducer placement, and transducer manipulation.

Coupling and the Acoustic Interface

To obtain adequate ultrasound images, a path for transmission of sound waves between the transducer and the object being imaged is necessary. This path is called an acoustic interface; it is achieved through coupling. Coupling is a process that displaces air (an inefficient sound transmitter) between the transducer and the object with a more efficient transmitter. In TAUS, a gel is the most common coupling agent (Fig. 4.5); for IOUS/LUS, a little saline placed on the surface of the organ works well.

Changing the thickness of the acoustic interface moves the transducer closer or farther from the object of interest, thereby altering the underlying image. This relationship allows several methods of scanning depending on the transducer's relationship to the structure of interest (Table 4.1). These different scanning techniques have specific uses as outlined in this and later chapters. This is particularly important for objects of interest in the near field (between the focal zone and the transducer); when they are too close to the transducer, they cannot be seen or the image suffers from low resolution.

Transducer Placement

The surgeons' intimate knowledge of three-dimensional anatomy facilitates recognition and interpretation of ultrasound images. This familiarity allows pattern recognition of organs and structures based on past experience. Transducer

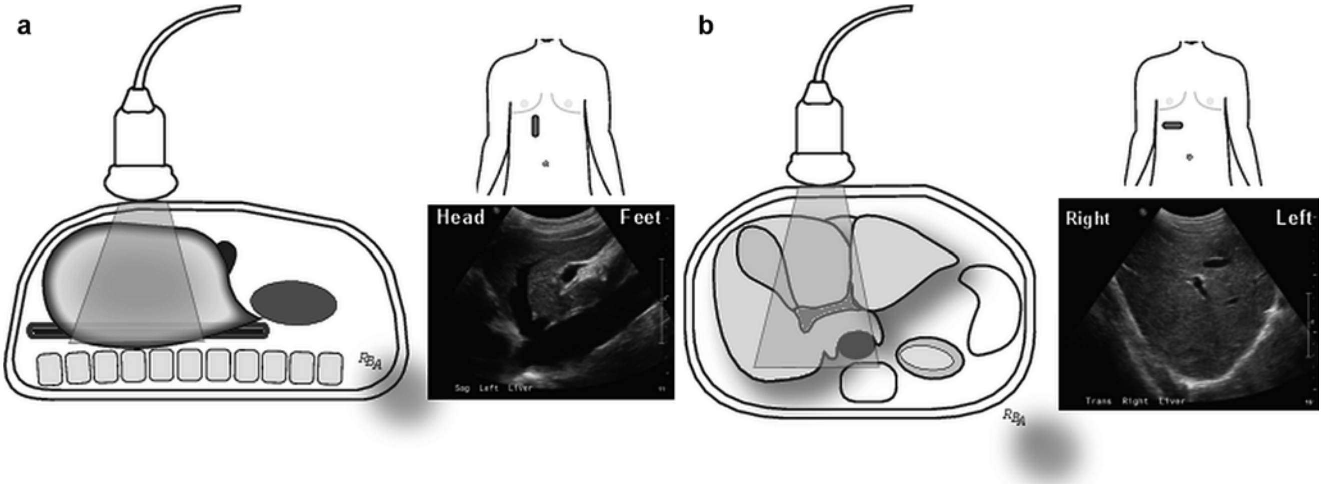

Fig. 4.4 Standard orientation and annotation of images is important for clearly communicating information represented by still images. (**a**) Transabdominal image with the transducer oriented in the longitudinal (sagittal) plane. By convention the image is oriented such that the patient's head is in the direction of the left side of the monitor. (**b**) Transabdominal image with the transducer oriented in the transverse (axial) plane. By convention the image is oriented such that the right side of the patients' body is oriented in the direction of the left side of the monitor

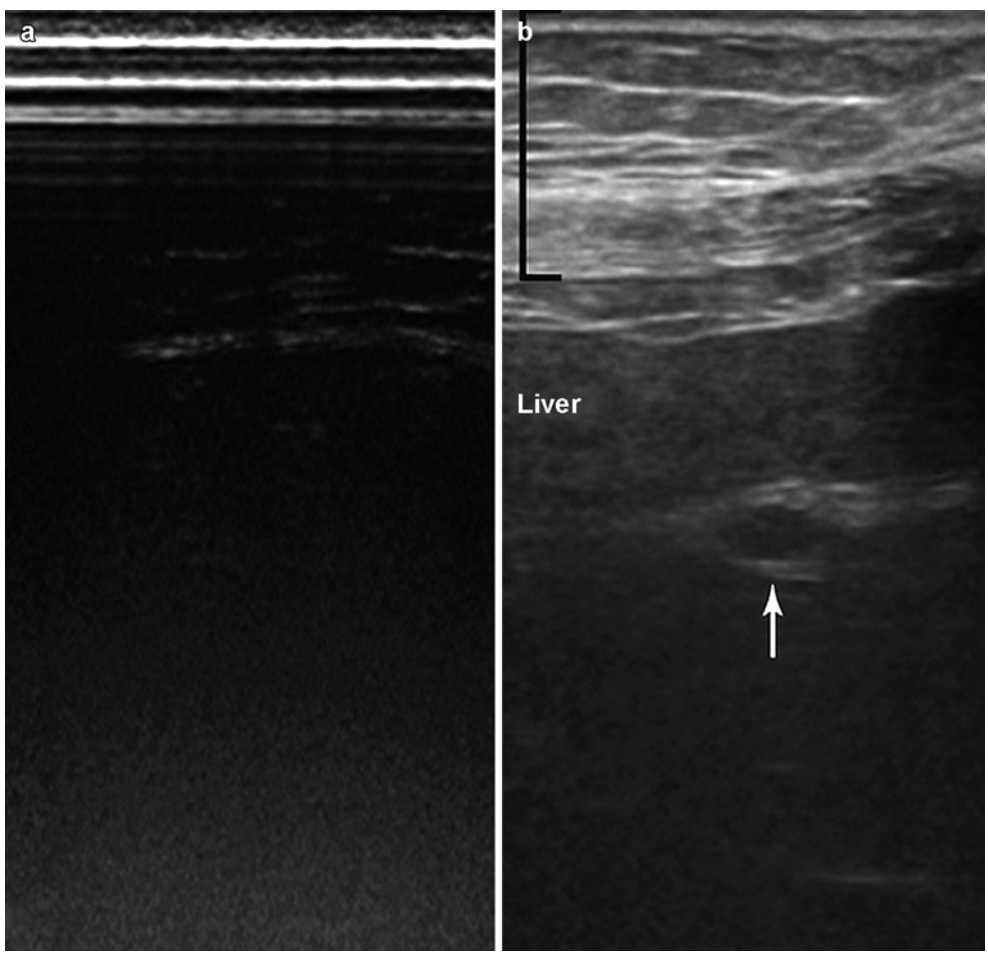

Fig. 4.5 Transabdominal ultrasound. (**a**) The transducer is placed on the skin without coupling gel. No discernible structures can be seen without an acoustic interface. (**b**) Gel is placed on the transducer and used to "couple" the transducer to the skin. This provides an acoustic interface that permits sound wave transmission and consequently an image. Seen in this image are the body wall (*black bracket*), the liver, and the left portal vein (*white arrow*)

Table 4.1 Types of scanning

Contact	
	Light contact
	Graded compression
	Deep compression
Probe standoff	
	Saline-filled bag/glove
	Saline immersion of organs (intraoperative/laparoscopic ultrasonography)

placement is important to find "acoustic windows," which are transducer placement sites that allow examination and recognition of the organ of interest. This requires considerable practice, patience, and a few tricks. However, matching the acoustic window with the surgeon's deep understanding of the underlying anatomy makes learning this easier.

Transducer placement is determined by the type of scan being performed. These are reviewed in detail in the next sections. In addition, it is important to examine an organ or structure of interest in two planes to insure that the image is not due to an artifact. This includes both the longitudinal and transverse planes but also on occasion an oblique plane. Thus, transducer placement and movement is important to achieve this goal. Finally, the degree of transducer placement against the tissue alters the image and the scanning method may change based on the structure being imaged.

The next step for proper transducer placement is determining the type of contact between the transducer and the object for imaging (Table 4.1). *Contact scanning* occurs when the transducer is placed in direct contact with the tissue of interest. It can vary from light contact to deep compression, depending on the purpose of the scan. The majority of TAUS exams use light, direct contact scanning. If organ displacement is desirable during TAUS, for instance, to move a loop of bowel with gas lying over a structure of interest, then deep compression can be used to move it aside, exposing a better acoustic window. Similarly, light contact scanning is frequently used for liver scanning; occasionally deep compression is necessary to change the angle of viewing or to displace gas within an organ when viewing through the organ such as imaging the pancreas through the stomach or gastrocolic ligament. *Probe (transducer) standoff scanning* occurs when the probe is not in direct contact with the tissue of interest. Advantages of the probe standoff technique are outlined in Table 4.2. In probe standoff scanning, acoustic coupling is achieved by placing a fluid interface between the transducer and scanned structure. For instance, better images are obtained when scanning a superficial, subcutaneous object by placing a saline-filled glove on the skin and scanning through this to move the transducer 1–2 cm away from the surface of the skin. Probe standoff scanning is done frequently during IOUS/LUS, either by filling the abdominal cavity with saline or placing a saline-filled glove on the organ and scanning through the fluid-filled acoustic window.

Table 4.2 Probe standoff scanning advantages

Allows placement of the object of interest into the focal zone
Eliminates artifacts due to an irregular scanning surface
Objects within 1–1.5 cm of the scanning surface can be seen
Superficial objects are seen with high resolution
Lack of tissue compression eliminates distortion of underlying structures
Provides more angles of freedom for scanning maneuvers

Table 4.3 Transducer movements

Sliding – transducer remains in contact with scanning surface; it is slid in longitudinal or transverse plane
Rotating – transducer is spun clockwise or counterclockwise; central portion remains fixed to starting site
Rocking – transducer is moved (rocked) parallel to the scanning plane
Tilting – transducer is moved perpendicular to the scanning plane

Transducer Manipulation

After determining the type of probe contact, the next critical steps to master are the transducer movements (Table 4.3). Too much transducer movement is a common error early in the learning process. Most transducers have a wide viewing area, and movement of the transducer more than a few millimeters results in significant changes in the image. The novice becomes "lost" when the familiar patterns of a recognized image are no longer seen, requiring one to restart the process by identifying a recognizable structure or pattern. A second common error is lifting the transducer when moving it, which causes the image to disappear when the acoustic interface is interrupted, again causing the novice to lose a pattern they recognize. Lifting the transducer eliminates one of the unique and important features of ultrasound, that is, real-time image acquisition and viewing. To eliminate these errors, four basic types of transducer movement are outlined (Fig. 4.6).

Once the first acoustic window is identified and the transducer placed, the probe is moved by "sliding" it across the tissue surface (Fig. 4.6a), eliminating the need to lift from the scanning surface. Sliding can be done with the probe in a longitudinal or transverse orientation. Sliding gives a series of parallel images in relation to the original scan plane. Once the area of interest is identified, the probe can be rotated, rocked, or tilted to scan the object and its surrounding structures. Rotation involves spinning the probe as if the central part of the transducer was stuck to the tissue (Fig. 4.6b). This allows imaging of the structure of interest continually

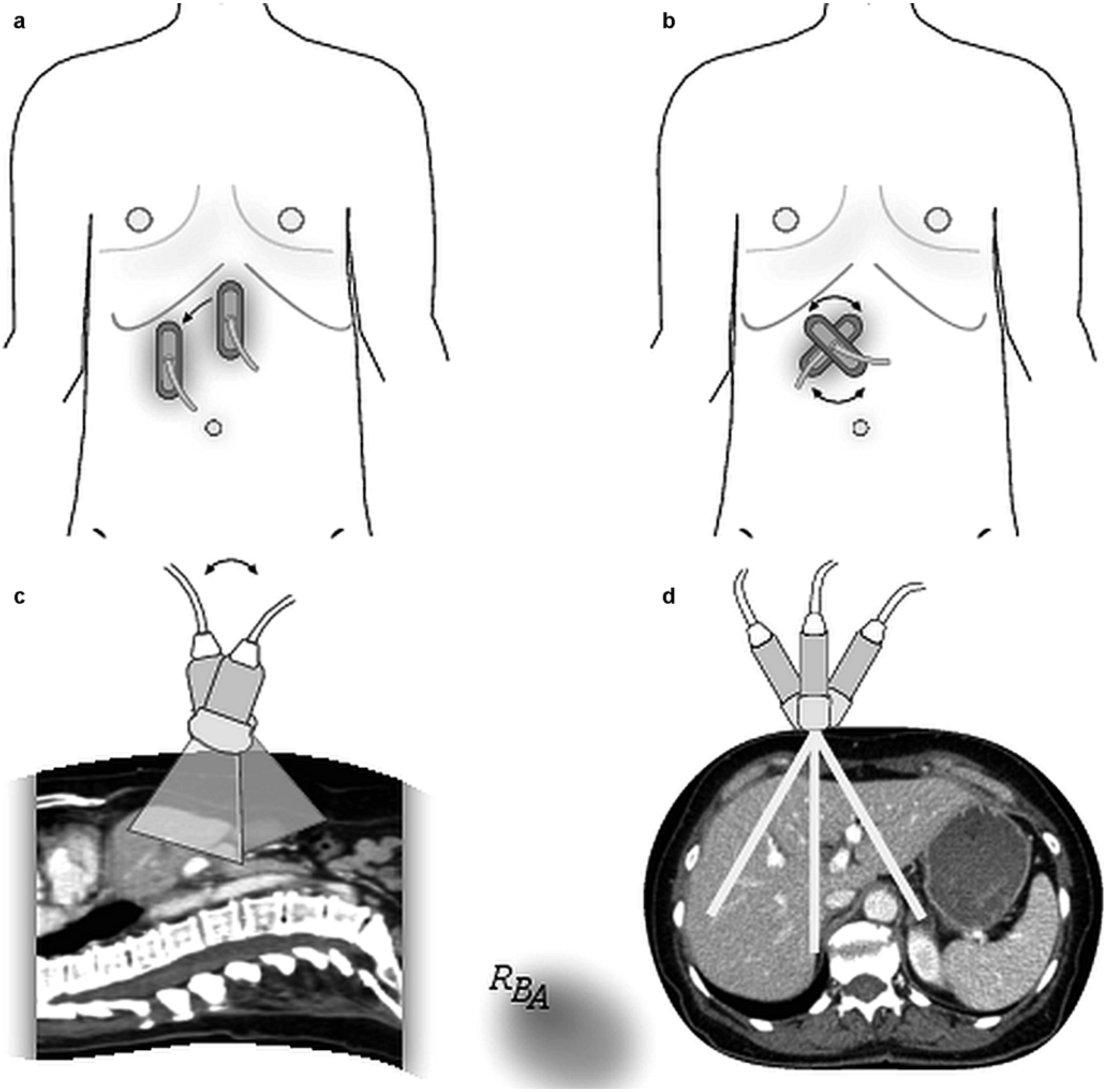

Fig. 4.6 Transducer movements. (**a**) Sliding. The transducer is moved without picking it up off the abdominal wall. (**b**) Rotating. The transducer is rotated clockwise or counterclockwise as if it were "pinned" to a central axis. (**c**) Rocking. The transducer remains in the same position relative to the skin while moving the back of the probe forward or backward in relationship to its long axis. This results in a series of images parallel to the scanning plane. (**d**) Tilting. The transducer remains in the same position relative to the skin while moving the back of the probe side to side relative to the long axis of the probe. This results in a series of images perpendicular to the scanning plane

through the longitudinal, oblique, and transverse planes, allowing one to develop a three-dimensional image. During rocking, the transducer moves parallel to the original plane of imaging (Fig. 4.6c). Tilting is the result of moving the probe perpendicular to the original scanning plane (Fig. 4.6d).

These small movements allow scanning of large areas with very little transducer movement in relationship to its site of contact with the tissue. Detailed images of the structures of interest can be achieved without getting lost during the scanning process. This allows scanning of the target in at least two dimensions to insure the object is not an artifact. In addition, scanning in multiple dimensions in real time allows one to develop a three-dimensional understanding of the structure or organ of interest.

Finally, it is critical to develop a systematic scanning approach for each type of scan you do and for each organ. To insure a complete examination, this system should be followed fastidiously every time an ultrasound examination is performed.

Transabdominal Ultrasound

TAUS done by surgeons is typically a focused examination seeking specific information for diagnostic or therapeutic reasons. It does not substitute the need for radiological expertise or other imaging studies, but rather is complimentary to these.

TAUS usually begins with the patient in the supine position. The examiner is on the patient's right side and the ultrasound machine is on the same side toward the head of the bed. A 3.5 MHz curvilinear transducer is the most common one used in adults. The curvilinear transducer requires a larger, flatter surface for optimal contact. When a smaller "footprint" (size of the contact surface) is necessary, such as viewing through an intercostal space, a phased array transducer can be used. Ideally, prior to TAUS, the patient should fast for 6 h. This decreases bowel gas and allows gallbladder distension.

Standard scanning planes for TAUS are those previously described: longitudinal (sagittal, coronal) and transverse. Most TAUS scanning is done with light contact with coupling accomplished with gel. When holding the transducer, it is helpful to stabilize your hand by placing the base of the hypothenar eminence against the body (Fig. 4.7). This allows for fine probe movement during the examination. The initial transducer placement depends on the type of study or organ of interest. The same is true for the initial transducer orientation. Transducer movement during TAUS includes all the techniques previously described.

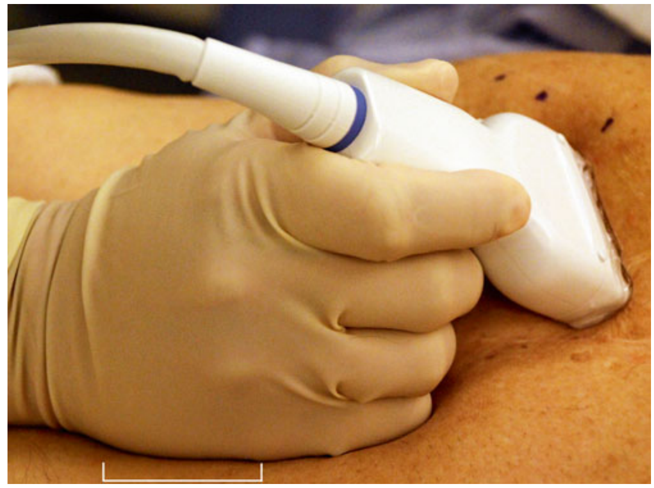

Fig. 4.7 During transabdominal ultrasound, it is helpful to hold the probe while lightly resting the hypothenar eminence (*white bracket*) against the body wall. This stabilizes the probe and allows for fine movements, steadies the image, and decreases fatigue

Liver Scanning Technique

Current transducers have a range of frequencies. A 3.0–3.5 MHz range is a good choice for most patients when evaluating the liver. A 5 MHz frequency may be better for very thin patients, while a 2.5 MHz frequency is helpful for obese patients or those with steatosis. Again, it is important to develop a systematic approach to scanning; it should be done every time. To begin liver imaging, place the probe transversely in the subxiphoid position and identify the hepatic veins as they join the vena cava. This is an easily recognized image that helps to orient the examiner (Fig. 4.8). If the patient has a steep, angulated costal margin, ask the patient to take a half to whole breath and hold it. This pushes the liver toward the costal margin, making the superior liver easier to see. Once this view is found, a systematic approach (Table 4.4) using a combination of transducer movements allows mapping of the segmental hepatic anatomy. For instance, a majority of the liver can be seen by rocking and tilting the probe while in the subxiphoid window (Fig. 4.9). Next, the probe is slid toward the left and then the right, allowing views of the remaining left and right livers, respectively. Upon completing the transverse views, the probe is reoriented in a sagittal plane and the process repeated. Sometimes the probe must be angulated sharply toward the head to scan beneath the costal margin. If this does not permit adequate viewing, an intercostal window allows access to structures hidden beneath the ribs. A smaller footprint probe is useful in this instance. Both an anterior and lateral approach through the costal margin may be necessary to image the structures of interest.

Biliary Scanning Technique

The transducer and techniques are similar to those described for the liver. Ideally, the patient should fast for 6 h prior to the study to allow maximal gallbladder distension. With the patient supine, position the probe subcostal in the midaxillary line while oriented in the sagittal plane. The initial step is to find the gallbladder. Slight sliding and tilting in this position allows a long axis view of the gallbladder (Fig. 4.10). Rotating the probe in the same position allows transverse and oblique views of the gallbladder. From here, several standard probe positions are helpful for complete biliary scanning (Fig. 4.11) [1]. Intercostal windows typically are necessary for complete biliary scanning. Rolling the patient into the left lateral decubitus position is important to distinguish

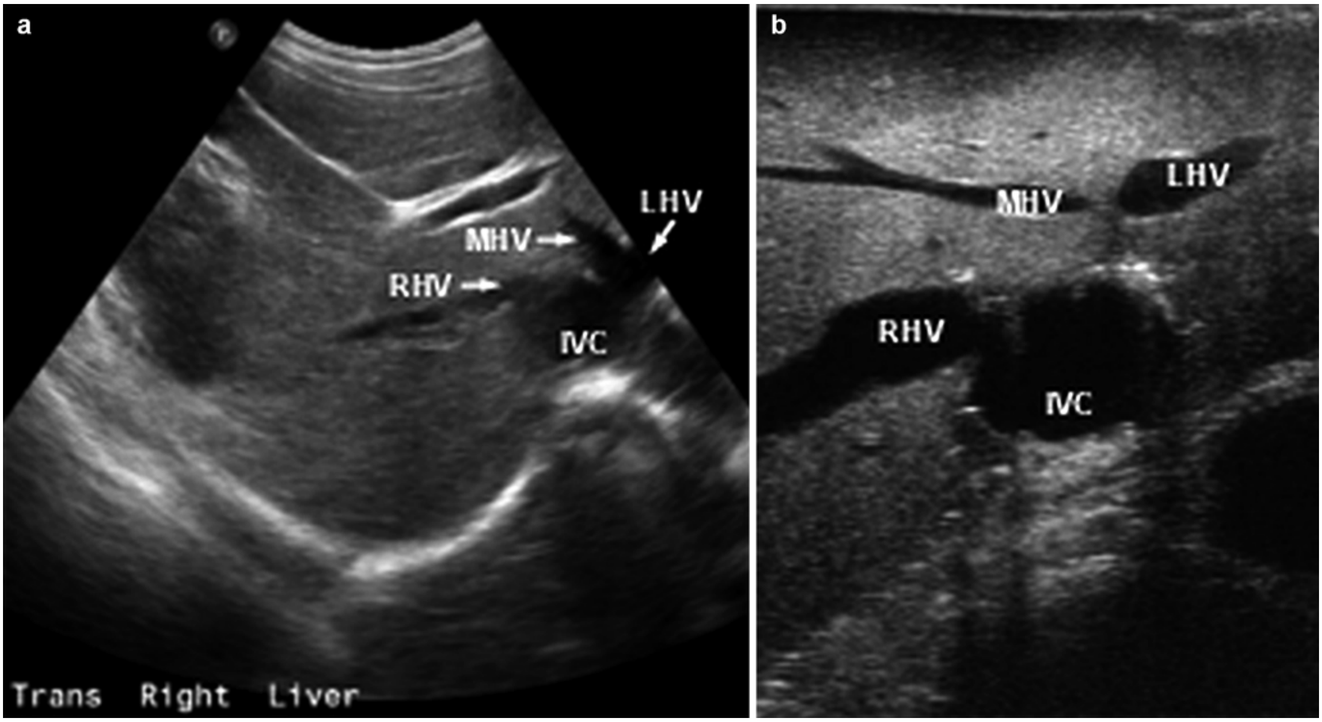

Fig. 4.8 Transabdominal ultrasound image with the transducer held transversely in the subxiphoid position. This allows a prototypical image of the hepatic veins as they join the vena cava (*IVC*). Right (*RHV*), middle (*MHV*), and left (*LHV*) veins are shown

Table 4.4 Stepwise approach to liver scanning: transabdominal

Identify hepatic veins
Find junction with vena cava
Follow to terminal branches
Identify any anomalous branches
Follow vena cava from hepatic vein branches to inferior liver
Identify portal branches
Find bifurcation, main, right, left portal veins
Follow right and left veins to their segmental branches
Systemic parenchymal scan
Develop a standard scanning approach
Examine all the parenchyma
Note lesion location, size, and features
Identify any vasculobiliary involvement or thrombosis

whether gallbladder masses are stones (move with repositioning) or polyps (stationary with repositioning) and sometimes to get an adequate view of the extrahepatic bile duct.

The extrahepatic bile duct is recognized by its position anterior to the portal vein. Place the probe in a longitudinal plane approximately perpendicular to the right costal margin between the midaxillary line and the epigastrium (Fig. 4.11, position b). Identify the portal vein at the hilar plate and follow it caudally to identify the bile duct in a longitudinal view anterior to the portal vein (Fig. 4.12). Sliding the probe toward the midline while in a longitudinal or oblique position allows viewing of the distal duct (Fig. 4.11, positions e and f). If the duct is not visible in this position, the best view may be obtained by placing the probe in a longitudinal, subcostal, and midaxillary position while the patient is in the left lateral decubitus position. Views of the retroduodenal duct are difficult to obtain as they often are obscured by duodenal or bowel gas. The intrapancreatic duct is best seen in transverse section through the head of the pancreas; however, this can be difficult to obtain due to bowel gas. Unless dilated, small intrahepatic ducts can be difficult to see. Intercostal windows facilitate imaging the right intrahepatic ducts, while the left ducts are viewed from a left subcostal window.

Pancreas Scanning Techniques

TAUS of the pancreas can be difficult due to bowel gas between the abdominal wall and the pancreas. The patient is examined in the supine position after fasting to minimize bowel gas. If the view still is impeded by gas, several other techniques can be used to improve the view. Deep inspiration and breath holding may push the liver below the costal margin where it can serve as an acoustic window to the pancreas. Compression scanning with deep pressure on the probe can push gas-filled structures aside. Placing the patient in a semi-upright position after drinking 500 ml of water may allow a viewing window through the fluid-filled stomach. A right

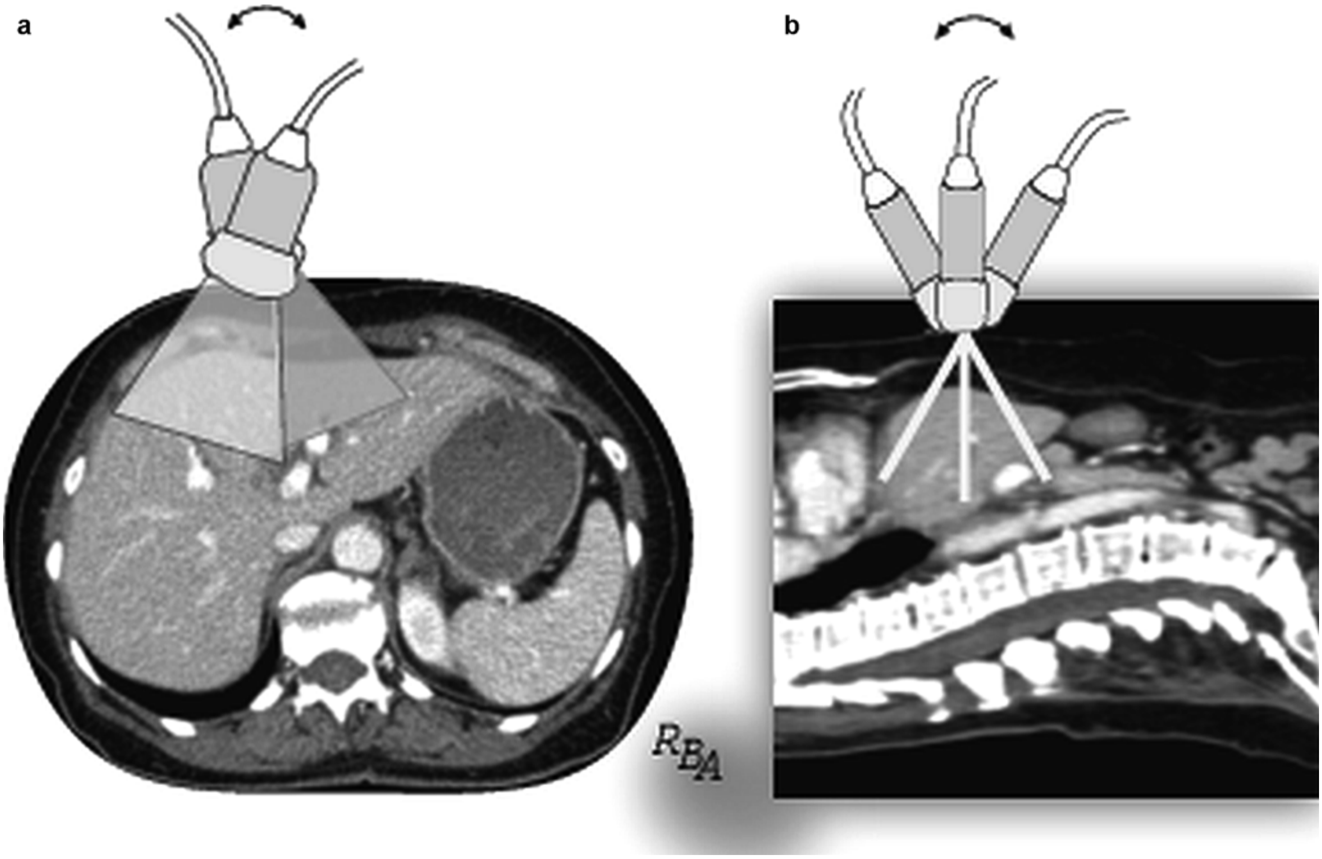

Fig. 4.9 Transabdominal ultrasound with the transducer placed transversely in the subxiphoid position. Rocking (**a**) and tilting (**b**) the probe in this single position allow one to image a large portion of the liver with relatively little probe movement relative to the body wall

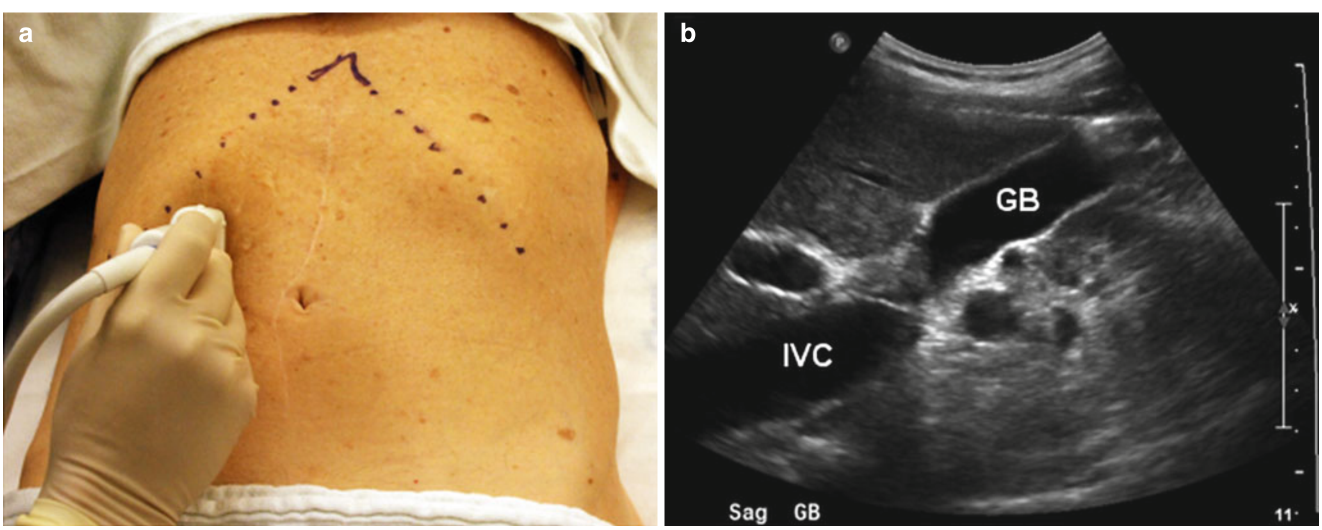

Fig. 4.10 Gallbladder imaging. (**a**) The transducer is oriented in the sagittal plane in the midaxillary line. (**b**) This allows a longitudinal view of the gallbladder (*GB*). Inferior vena cava (*IVC*)

lateral decubitus position may improve the image. Finally, the tail of the pancreas may be best seen from a left lateral flank view through the spleen.

The pancreas is difficult to find on TAUS. It is most easily identified by its relationship to surrounding landmarks. The transducer is positioned transversely in the subxiphoid,

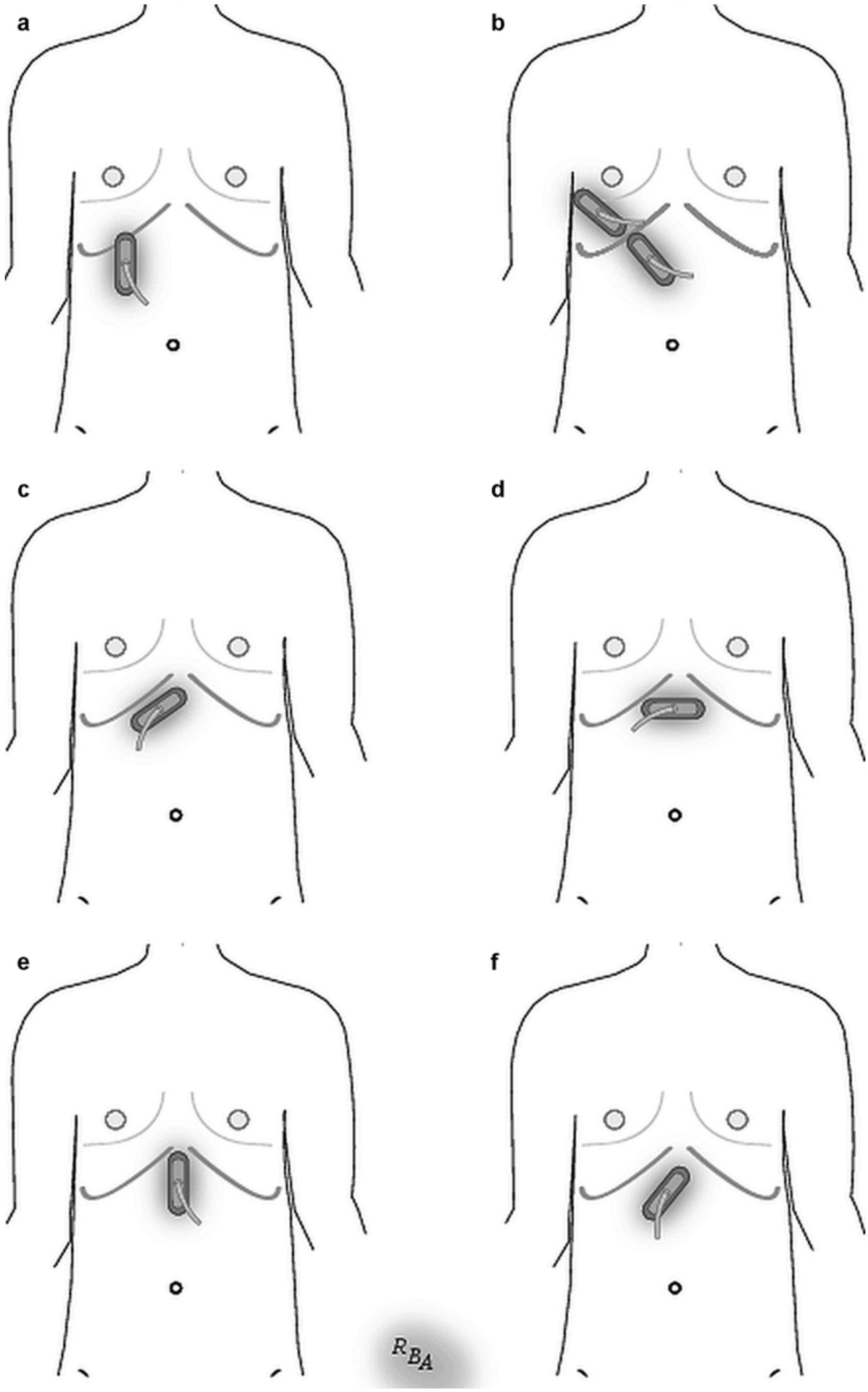

Fig. 4.11 Standard transducer positions for transabdominal biliary imaging. (**a**) The probe is positioned sagittally in the right subcostal, midaxillary position to view the gallbladder. (**b**) Right intercostal space, oblique position allows gallbladder, right intrahepatic duct, and right portal triad imaging. Right epigastric, oblique position allows viewing of the proximal extrahepatic porta hepatis. (**c**) Right subcostal, oblique position shows the right and left hepatic ducts. (**d**) Subxiphoid transverse position shows the left lateral section bile ducts. (**e**) Subxiphoid midline, or right paramedian, sagittal position allows imaging of the mid to distal extrahepatic bile ducts. (**f**) The distal-most portion of the common bile duct is seen from a left oblique upper abdominal position (Adapted from [1])

midline position. The pancreas is identified by first finding the vertebral body, aorta, vena cava, and the splenic vein junction with the superior mesenteric vein. The pancreas can be inferred by its relationship to these structures. Figure 4.13 shows the prototypical image used to identify the pancreas. Once the neck and body are seen, the remaining portions of the gland are examined in the transverse plane and then the longitudinal plane.

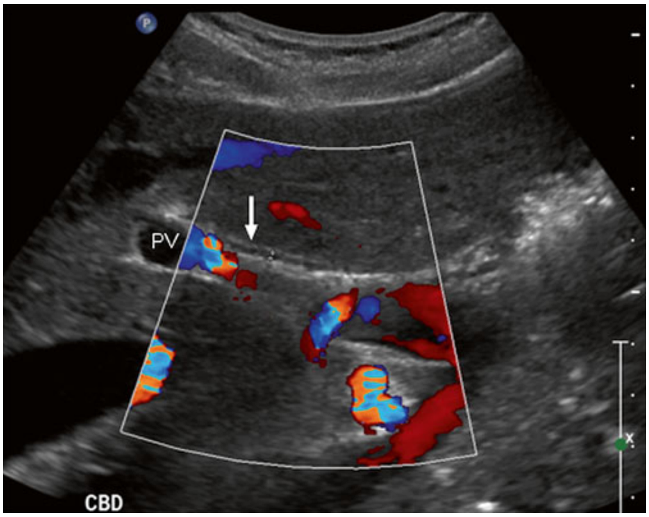

Fig. 4.12 Transabdominal ultrasound of the extrahepatic bile duct. The probe is positioned in the sagittal plane. The bile duct (*white arrow*) lies anterior to the portal vein (*PV*). Color Doppler is helpful to distinguish vascular structures from the bile duct

Fig. 4.13 Transabdominal ultrasound of the pancreas. The transducer is placed in the transverse plane in the midline just inferior to the xiphoid. This is the prototypical image of the vasculature surrounding the pancreas that facilitates its identification. The anterior border of the pancreas is denoted by the *white arrows*. The pancreas lies just anterior to the superior mesenteric vein (*SMV*) and the splenic vein (*white line*). Other vascular structures that comprise this prototypical image include the aorta (*Ao*), the inferior vena cava (*IVC*), and the superior mesenteric artery (*). The left renal vein (*LRV*) also can be seen

Open Intraoperative Ultrasound

Intraoperative ultrasound has become an indispensable part of abdominal surgery. It is a critical tool to evaluate and manage hepatic, biliary, and pancreatic diseases. IOUS has the advantage of being the only real-time, intraoperative imaging technique available in the operating room. Finally, it can be reused repeatedly throughout a procedure to reevaluate and guide the operation.

The ultrasound machine and monitor are placed on the side of the table opposite the ultrasonographer. Choosing the appropriate transducer type and frequency is determined by the nature of the examination and the target organ. If the transducer is sterilized, no cover is necessary and direct scanning without an acoustic interface is done. If a non-sterile transducer is covered by a sterile cover, gel must be placed into the cover around the probe to insure adequate coupling. IOUS, like TAUS, uses contact and standoff scanning techniques and similar probe movement and manipulation to obtain images. Unlike TAUS, IOUS scanning planes are in relationship to the organ being scanned, not the body, thus differing in some instances to conventional TAUS planes.

Liver Scanning Technique

A flat, side-viewing, linear array transducer is favored for liver scanning. The long footprint allows efficient imaging of the whole organ and gives a rectangular image of the underlying structures (Fig. 4.14). Images in this configuration make interventions, such as needle biopsy, relatively easier compared to a curvilinear array. The probe's low profile allows easy access in limited working spaces between the liver, abdominal wall, and diaphragm. While current probes are multifrequency, scanning in the 7.5 MHz range has the most utility for liver IOUS. This frequency allows adequate penetration to view the whole organ while showing the very fine detail of intrahepatic structures. A lower frequency, 5 MHz, may be necessary for a larger, steatotic, or cirrhotic liver since this frequency results in deeper sound penetration to examine the depths of the parenchyma in these organs.

Similar to TAUS, a critical component for successful IOUS is developing a systematic scanning approach for the liver. Fastidious adherence to this system insures an adequate and thorough evaluation every time an examination is performed. The first step of this approach is identifying the segmental anatomy. Once each segment is mapped, an evaluation for known and occult lesions is undertaken, noting their location and relationship to the segmental anatomy and intrahepatic structures.

Hepatic IOUS begins with contact scanning (Fig. 4.15, position A). Moistening the liver's surface with saline is sufficient to create coupling. The probe is placed in direct contact with the liver; knowing its exact position on the organ is an advantage of IOUS, making image interpretation easier. Contact scanning is useful for imaging most of the liver; however, it is of limited utility when a mass or structure is within 5–10 mm of the probe (Fig. 4.16). Thus, superficial areas directly beneath the probe represent a "blind spot" during

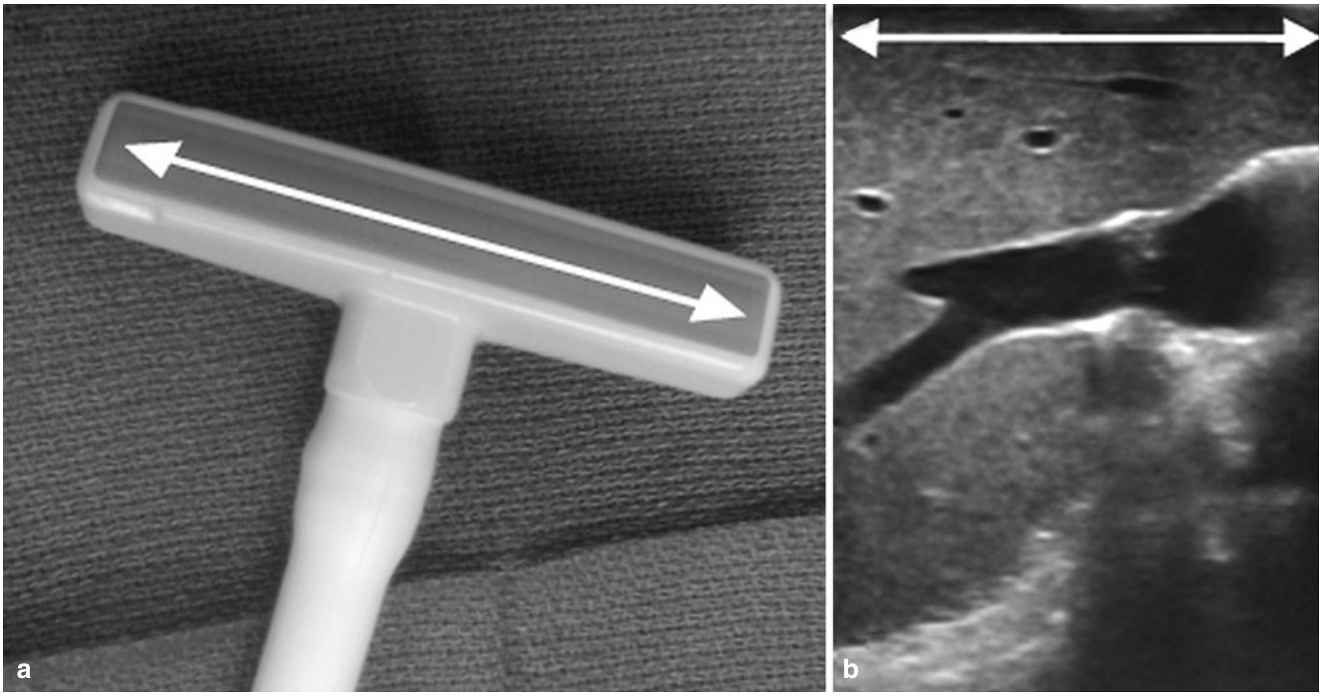

Fig. 4.14 (**a**) Intraoperative linear array transducer. This probe has a relatively large "footprint" due to its long crystal array (*white arrow*). (**b**) This results in a long, rectangular image

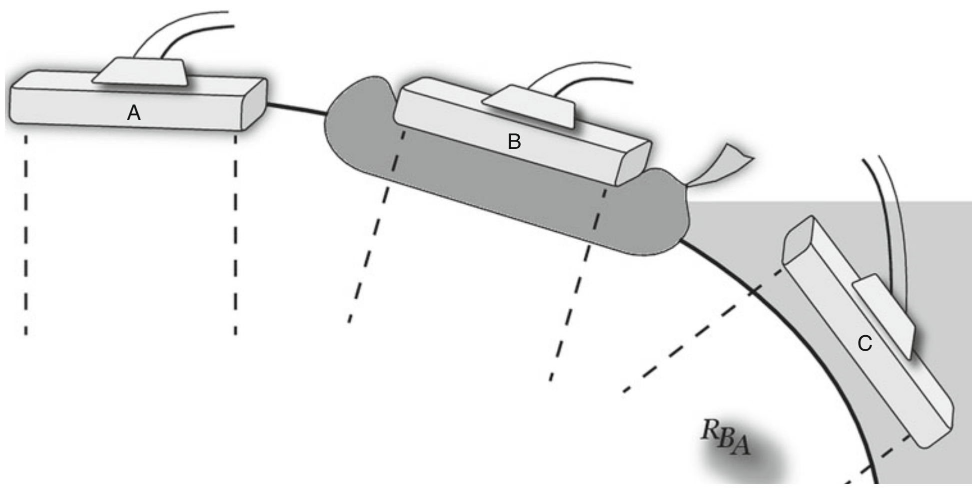

Fig. 4.15 Probe placement for intraoperative ultrasonography. (*A*) Contact scanning places the transducer directly in contact with the organ's surface. (*B*) Probe standoff scanning using a saline-filled glove. (*C*) Probe standoff scanning using saline (*gray area*) immersion. Probe standoff techniques hold the transducer away from the organ surface to allow imaging of superficial structures

contact scanning. Similarly, irregular surfaces (e.g., cirrhosis) make scanning difficult, leading to poor image quality. It is these circumstances when a probe standoff technique for scanning is of use (Fig. 4.15, positions B and C). Saline is an effective interface to establish an acoustic window between the probe and the surface of the liver for a probe standoff technique. With the transducer separated from the liver surface, superficial structures or the irregular surface are seen with better clarity and resolution than during contact scanning. Probe standoff scanning can be done in several ways as illustrated in Fig. 4.15. The difficulty with image resolution of superficial lesions by IOUS emphasizes the importance of combining inspection and palpation when examining abdominal organs, since these techniques are complementary to IOUS. Each of these examination methods should be used to insure complete evaluation of the liver.

The liver examination begins with transverse scanning followed by, longitudinal and oblique views (Fig. 4.17). Together, images in these planes define intrahepatic structures and verify lesions by demonstrating their presence in two or more dimensions. Rotating the probe over a fixed point allows examination of the underlying structure in several planes, a quick but important way to insure the object of interest is not an artifact (Fig. 4.18). A wider field of view is achieved by rocking or tilting the transducer without sliding it in relationship to the contact point. This allows delineation

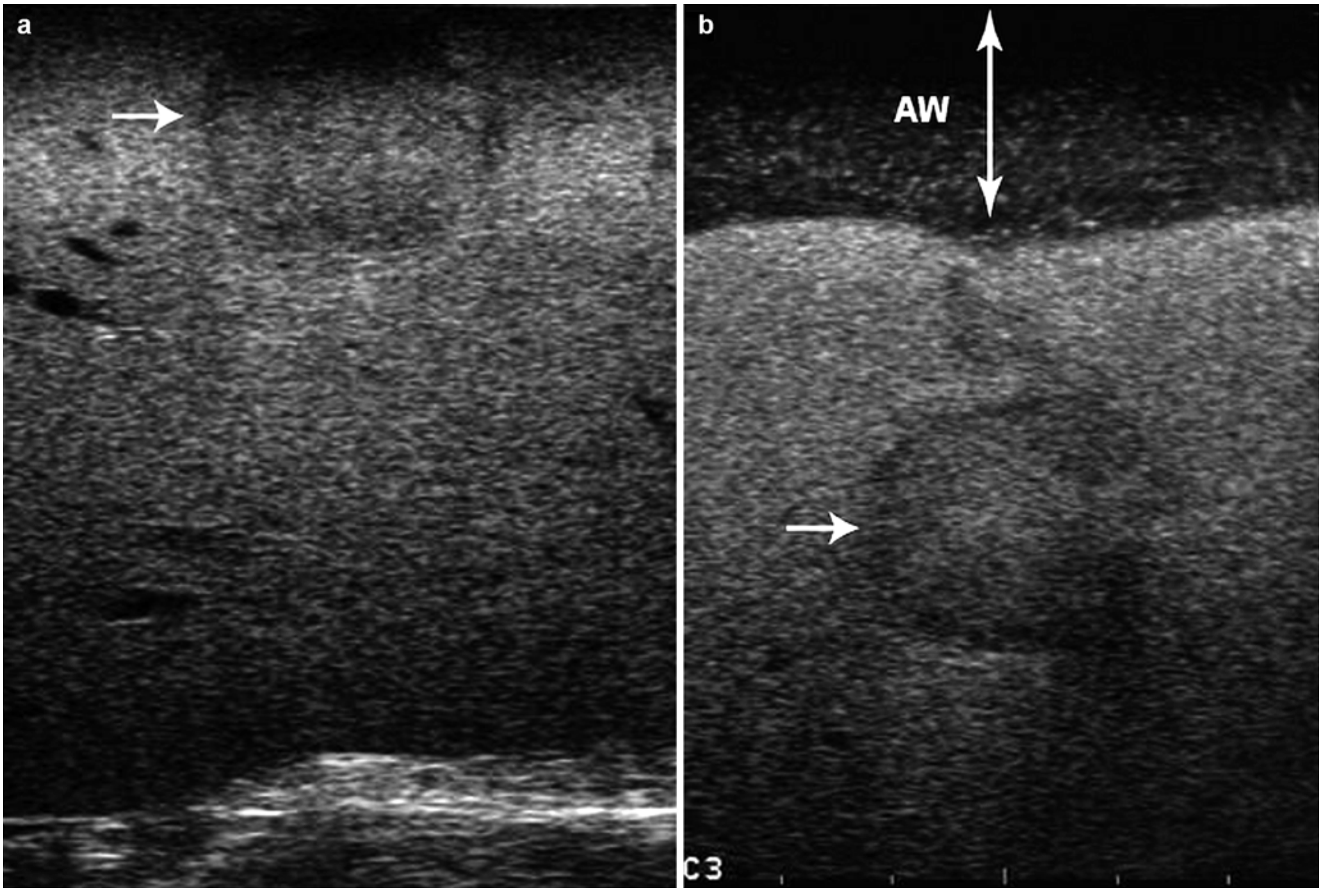

Fig. 4.16 Intraoperative imaging of a superficial liver mass (*white arrow*). (**a**) Contact scanning. (**b**) Probe standoff scanning using saline immersion allows a view of the entire mass, which cannot be seen in the contact scanning view. The saline provides the acoustic window (*AW*) for adequate viewing

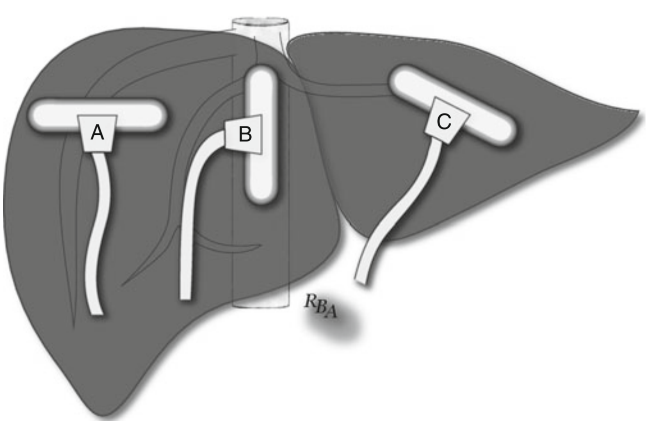

Fig. 4.17 Standard intraoperative transducer positions for liver scanning. (*A*) Transverse. (*B*) Longitudinal. (*C*) Oblique

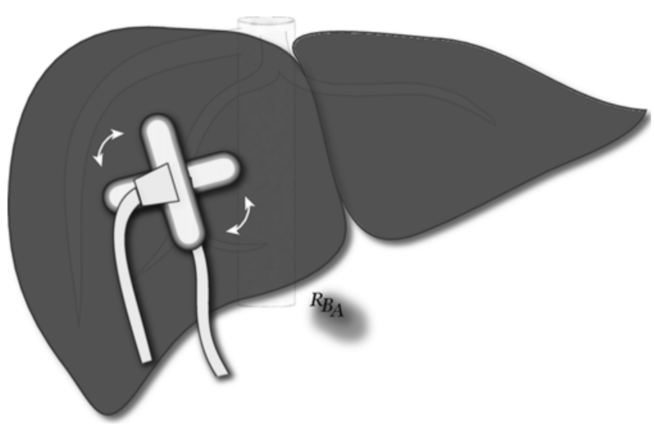

Fig. 4.18 Rotational transducer movement. The probe is rotated clockwise or counterclockwise on a fixed point. This allows examination of a structure or mass in two planes

of the relationship between structures in close proximity (Fig. 4.19). Rocking and tilting, when combined with saline immersion, allow superb views of the superior hepatic segments (Fig. 4.20).

Table 4.5 shows the steps for a systematic approach to liver scanning. The initial scanning is done without mobilizing the liver. This usually is sufficient for a screening examination. If resection or other intervention is planned, scanning before mobilization avoids artifacts, such as air, that may obscure the field of vision. A complete scan is repeated after mobilizing the liver. The primary goals of

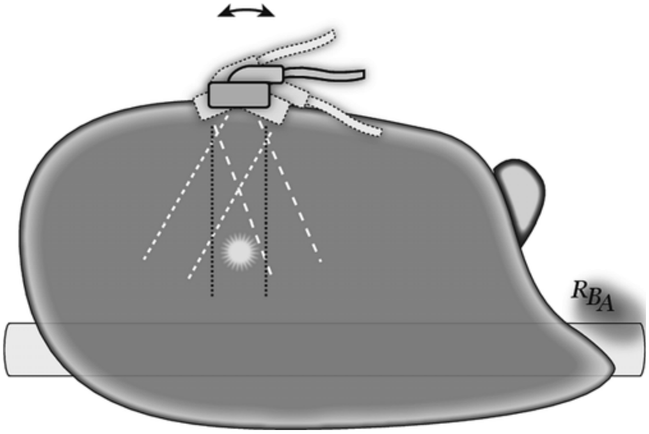

Fig. 4.19 Rocking/tilting transducer movement. The probe is "rocked" or "tilted" at a fixed point on the organ's surface. This allows examination of a wide area surrounding a structure of interest and prevents the examiner from "getting lost" by moving the probe too much

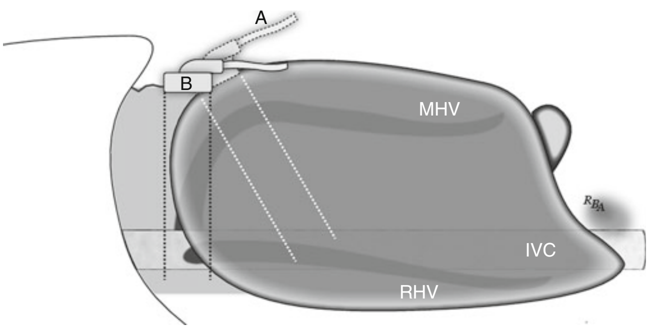

Fig. 4.20 Rocking/tilting combined with saline immersion. This technique allows an excellent view of the superior surface of the liver and its associated structures. (**a**) Contacting scanning along the superior liver gives a view of the central liver and portions of the hepatic veins (*MHV* middle hepatic vein, *RHV* right hepatic vein). However, imaging the junction of the hepatic veins with the inferior vena cava (*IVC*) can be difficult with contact scanning. (**b**) Probe standoff using saline immersion combined with rocking the transducer allows the crystal to be positioned in a way that allows imaging of the junction between the hepatic veins and the IVC

liver IOUS are evaluation of the segmental hepatic anatomy and vasculature and complete, systematic imaging of the parenchyma.

Prior to liver mobilization, initial attention is directed to:

1. Identify intrahepatic vascular anatomy. Segmental hepatic anatomy is defined by the hepatic veins and portal pedicles; these should be mapped first. They define the surgical anatomy of the liver.
   (a) Identify the junction of the major hepatic veins with the vena cava at the superior border of the liver. Follow each vein out to its terminal branches. The hepatic veins lie between sections of the liver [2]. Identify any anomalous hepatic veins, which are quite common. Identify any tumor involvement of the veins.
   (b) Identify the portal vein branches from the distal main portal vein to its bifurcation into the right and left branches and follow them out to their terminal branches. Again, vascular or biliary tract involvement by tumors should be identified.
2. Scan the entire liver parenchyma in a systematic fashion, identifying any known tumors and noting any occult lesions. Scan the liver in several planes and from various directions, including from the inferior and posterior surfaces, to fully evaluate any masses.
3. Establish the relationship between the portal and hepatic veins and any masses or anomalies. Multi-planar scanning allows construction of a three-dimensional mental model of the identified lesions and an understanding of their exact segmental locations and relationships to intrahepatic structures.

Table 4.5 Stepwise approach to liver scanning: intraoperative

Scan liver
Before mobilization
Repeat scan after liver mobilization
Contact scanning
Saline immersion probe standoff as necessary
Scan from inferior and posterior surfaces as necessary
Identify hepatic veins
Find junction with vena cava
Follow to terminal branches
Identify anomalous branches
Follow vena cava from hepatic vein branches to inferior liver
Identify portal branches
Find bifurcation, main, right, left portal veins
Follow right and left veins to their segmental branches
Systemic parenchymal scan
Develop a standard scanning approach
Examine all the parenchyma
Note lesion location, size, and features
Identify any vasculobiliary involvement or thrombosis

If the procedure requires liver mobilization, complete this and repeat the examination focusing on the following:

1. Repeat the systematic scan outlined above, but focus additional time on segment 7 (posterosuperior segment) and deeper portions of the liver that might not have been adequately seen on the initial survey prior to liver mobilization. Scan from the posterior and inferior surfaces of the liver if necessary.
2. Confirm the spatial relationship between identified lesions and the anatomic segments. Reassess the relationship or involvement of local vessels to any lesions. It is particularly important to develop a three-dimensional mental image of these relationships to understand how the anatomic relationships may appear different by IOUS when the liver's position is changed during resection or other interventions.

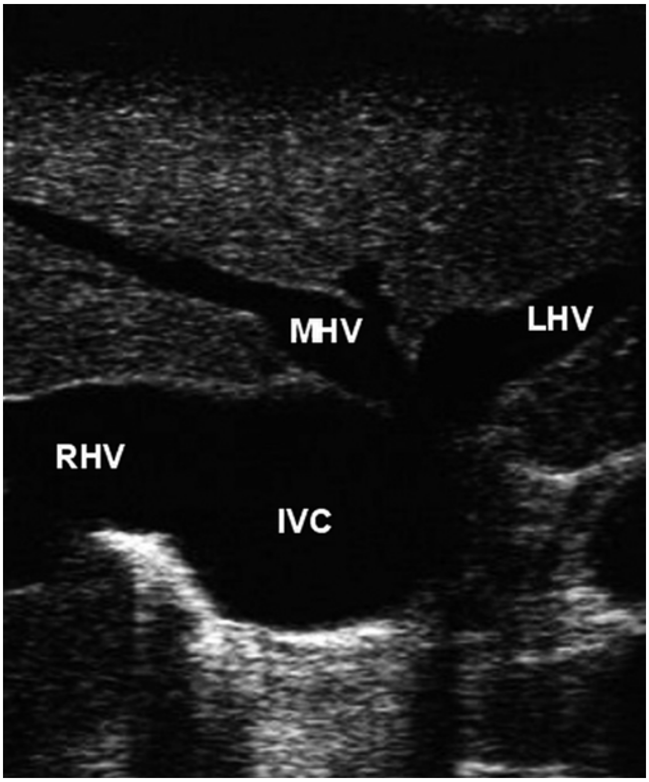

Fig. 4.21 Intraoperative ultrasound, transverse plane. This is the prototypical image seen at the superior border of the liver. The middle (*MHV*) and left (*LHV*) hepatic veins usually join to form a common trunk prior to joining the inferior vena cava (*IVC*). This has the appearance of "rabbit ears" and is a standard image that is helpful for orienting oneself during liver ultrasound. The right hepatic vein (*RHV*) is usually seen joining the vena cava in the same image

Fig. 4.22 Intraoperative ultrasound, longitudinal (sagittal) plane. The inferior vena cava (*IVC*) can be followed along its entire course in this plane. The middle hepatic vein (*white arrow*) is seen joining the vena cava

Begin contact scanning on the anterior liver surface and start the scan by identifying the intrahepatic vasculature. Find the junction of the three hepatic veins with the vena cava at the superior most portion of the liver by placing the probe over the upper portion of the falciform ligament. This gives a prototypical image of "rabbit ears" and is a fairly constant imaging feature that easily helps one get oriented at the beginning of the scan (Fig. 4.21). Once this image is obtained, each hepatic vein is followed peripherally to its terminal branches. Light contact scanning is necessary, as too much compression will cause the veins to collapse and they will not be visible. Next, reevaluate each vein in the longitudinal (sagittal) plane. In a similar way, the retrohepatic vena cava can be examined along its full length (Fig. 4.22).

A typical view of the hepatic hilum is acquired by contact scanning along the inferior aspect of the liver to the patient's right of the falciform ligament in the transverse plane (Fig. 4.23). The bifurcation of the portal vein is seen just distal to the termination of the main portal vein, allowing scanning of the right portal vein. It is followed peripherally to its division into the anterior (segments 5 and 8) and posterior (segments 6 and 7) sectorial branches (Fig. 4.24). Once the sectorial branches are seen, each can be followed to its superior and inferior segmental branches. In this fashion, the entire inflow to the right liver is mapped. Next, go back to the portal bifurcation view and follow the transverse portion of the left portal vein to the base of the umbilical fissure. At this point, the left portal vein travels anteriorly and inferiorly in the umbilical fissure. At this site, the left portal vein has the appearance of a tree trunk with branches coming off of the main trunk to its left and right (Fig. 4.25). Branches passing to the right of the umbilical fissure supply the medial section of the left liver (segment 4), while those traveling to the patient's left of the umbilical fissure supply the lateral section of the left liver (segments 2 and 3).

Completion of this portion of the study allows full delineation of the segmental anatomy of the liver and the intrahepatic vasculature. The systemic survey of the hepatic parenchyma follows next, seeking evaluation for diffuse and focal abnormalities, in particular mass lesions. Note the location of each previously known hepatic mass, as well as

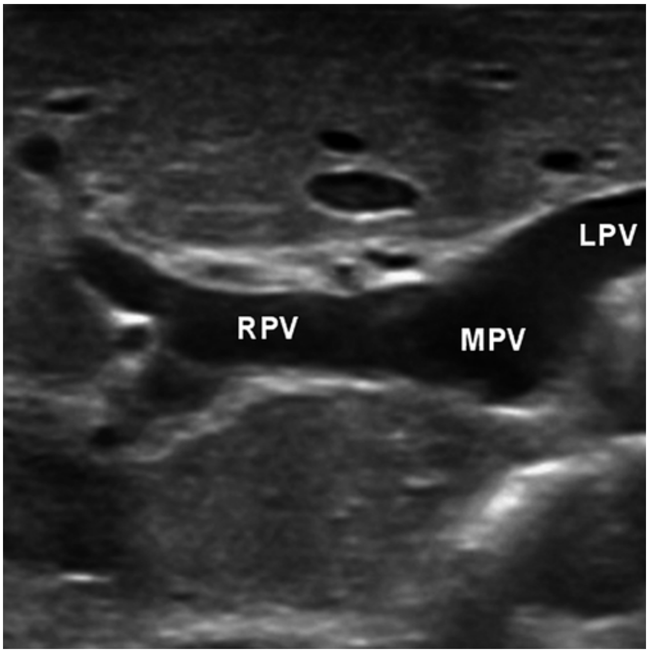

Fig. 4.23 Intraoperative ultrasound, transverse plane. View of the hepatic hilum through the anterior liver shows the main (*MPV*) portal vein as it branches into the right (*RPV*) and left (*LPV*) portal veins

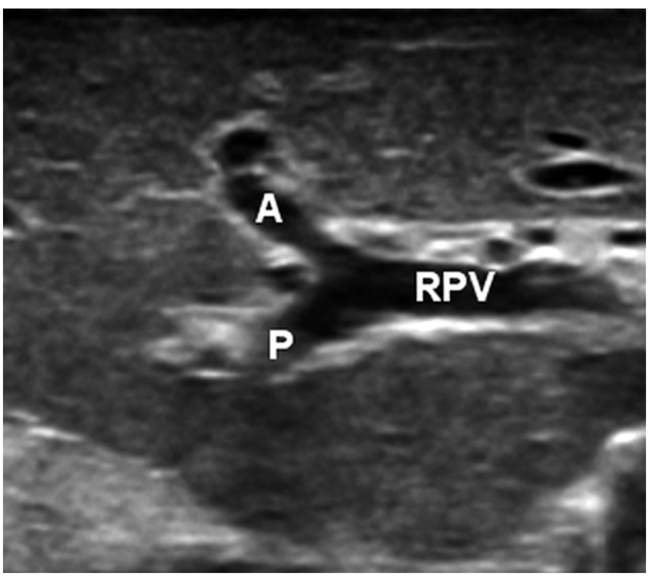

Fig. 4.24 Intraoperative ultrasound, transverse plane. View of the right portal vein (*RPV*) as it branches into its anterior (*A*) and posterior (*P*) sectorial branches

new, occult lesions found during the survey. Contact scanning should be done from the anterior and diaphragmatic surfaces of the liver. Again, develop a systematic approach that is used in every case to insure scanning of all segments of the liver. Finish the survey by scanning in the longitudinal plane. Alternative techniques may be necessary for complete scanning of segment 7 including a probe standoff technique or contact scanning from the posterior surface to see the entire segment. If the posterior sector is too deep to scan from the anterior surface, posterior contact scanning will allow adequate images. Finally, direct scanning of segment 1 may provide better images.

Strict adherence to this systematic approach for liver scanning will allow attainment of the goals outlined at the beginning of this section. A detailed knowledge of intrahepatic anatomy couple with these techniques will allow accurate localization of any structure or mass within the liver. This will facilitate intraoperative diagnosis of hepatic pathology and decision-making regarding the appropriate therapeutic approach.

Biliary Scanning Technique

Optimal biliary scanning often is best achieved using two different probes. Similar to hepatic scanning, a flat, side-viewing, linear array transducer is most useful for contact scanning of the gallbladder or extrahepatic bile ducts using the liver as the acoustic window or for imaging the intrahepatic bile ducts (Fig. 4.26). The gallbladder also can be scanned directly using a probe standoff technique, scanning the gallbladder from its inferior surface after filling the subhepatic fossa with saline. After scanning the gallbladder (Fig. 4.27a), the probe is slid toward the inferior edge of the liver, allowing a view of the hilar structures at the hepatic plate (Fig. 4.27b). Scanning further inferiorly gives transverse (cross-sectional) images of the hepatoduodenal ligament (Fig. 4.27c).

Scanning the extrahepatic bile ducts is best done with an end-viewing transducer at a frequency higher than 7.5 MHz. Table 4.6 shows a standardized technique for biliary scanning. Initial scanning should occur prior to any dissection of the gallbladder or hepatoduodenal ligament; this avoids introducing artifacts from the dissection. Likewise, if cholangiography is anticipated, ultrasonography is done prior to this. When learning biliary scanning, IOUS followed by cholangiography is an excellent way to compare the ultrasound findings to an accepted standard until you are comfortable performing and interpreting biliary IOUS images.

While contact scanning directly along the hepatoduodenal ligament may give adequate images if sufficient adipose surrounds the duct, the best views often are attained using a probe standoff technique following saline immersion of the ligament (Fig. 4.28). The longitudinal view (Figs. 4.29A and 4.30a) of the bile duct is the most useful, but transverse scanning (Fig. 4.29B, C) should be a part of the study. The supraduodenal bile duct can be examined from the hepatic plate to the superior edge of the duodenum or head of the pancreas using the standoff approach. Adequate images at the hilar plate may require probe angulation to fully examine the duct

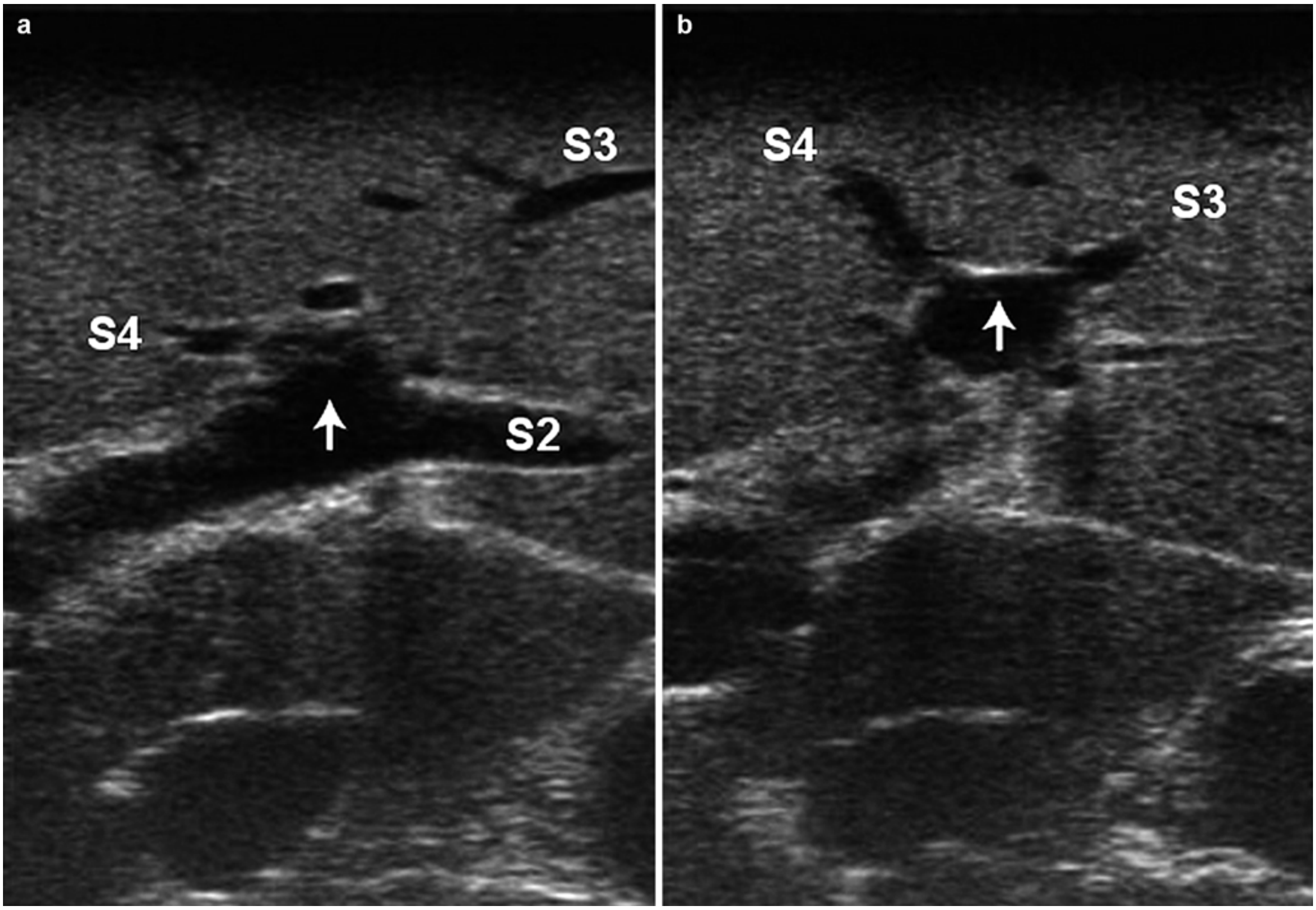

Fig. 4.25 Intraoperative ultrasound, transverse plane. View of the left portal vein (*white arrow*) and its segmental branches to segments 4 (*S4*), 3 (*S3*), and 2 (*S2*). The left portal vein and its branches often have a prototypical configuration, showing an image similar to a tree trunk with branches or a “dancing figure” with arms and legs. (**a**) View at the base of the umbilical fissure. (**b**) View further distal (more peripherally) from the umbilical fissure toward the ligamentum teres

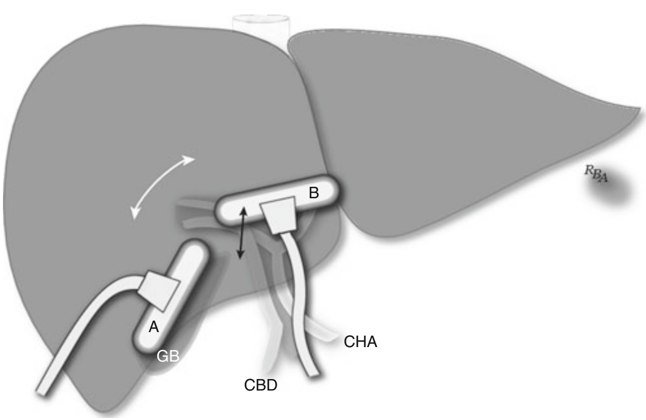

Fig. 4.26 Intraoperative biliary scanning. The gallbladder (*GB*) can be imaged using the liver as an acoustic window. The intrahepatic and proximal extrahepatic bile ducts (*CBD*) can be imaged similarly through the liver. The transducer can be oriented to show longitudinal (*A*) or transverse (*B*) images of these structures. Probe movement includes sliding (*black arrow*) or rotation (*white arrow*). Common hepatic artery (*CHA*)

at this site. The examination of the posterior duodenal and intrapancreatic bile duct requires use of compression scanning (Figs. 4.29C and 4.30b). Placement of the transducer on the anterior surface of the first portion of the duodenum followed by gentle compression will displace any duodenal air, giving a view of the bile duct. If the intrapancreatic portion is not visible from this position, move the probe over the pancreatic head, scanning through the pancreas itself. If the duct is not adequately seen with these techniques, standoff or compression scanning from a lateral (through the duodenum) or posterior approach after performing a Kocher maneuver to mobilize the duodenum and pancreatic head may provide better images. The junction of the bile duct with the duodenum is difficult to see unless the duct is dilated to the level of the ampulla or a stone is present in the very distal duct. Distinguishing between small bile ducts and vessels, particularly at the hepatic hilum can be difficult. Using color Doppler for this is very helpful in differentiating between these structures.

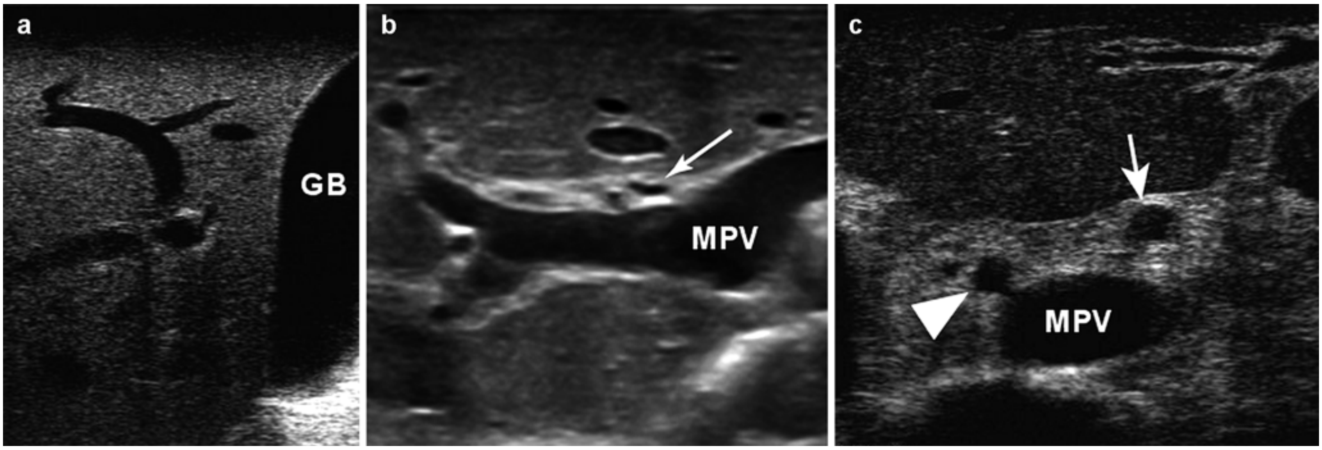

Fig. 4.27 (**a**) Longitudinal image of the gallbladder (*GB*) at the inferior edge of the liver. (**b**) Transverse view of the hepatic hilum. The *white arrow* points to the junction of the right and left hepatic ducts just proximal to the common hepatic duct. This lies anterior to the main portal vein (*MPV*). (**c**) Sliding the transducer further toward the inferior edge of the liver brings the hepatoduodenal ligament into view, showing the typical "Mickey Mouse" view of the common bile duct (*white arrowhead*), main portal vein (*MPV*), and common hepatic artery (*white arrow*)

Table 4.6 Stepwise approach to biliary scanning: intraoperative/laparoscopic

Scan gallbladder	
	Contact scanning, transhepatic
	Saline immersion probe standoff from inferior surface
Scan extrahepatic bile duct	
	Contact scanning, transhepatic
	Saline immersion probe standoff, transverse and longitudinal planes
Scan intrapancreatic bile duct	
	Transduodenal compression scanning
	Transpancreatic contact/probe standoff scanning

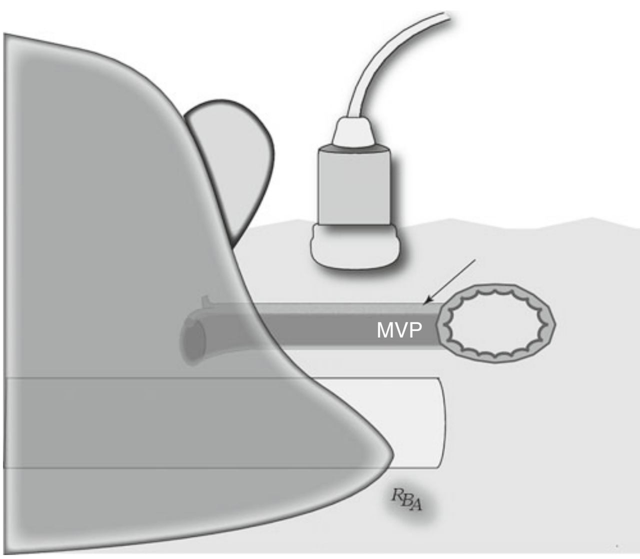

Fig. 4.28 Longitudinal (sagittal) scanning of the hepatoduodenal ligament a probe standoff, saline immersion technique. This allows very detailed images of the common bile duct (*black arrow*), which lies along the anterolateral surface of the main portal vein (*MPV*)

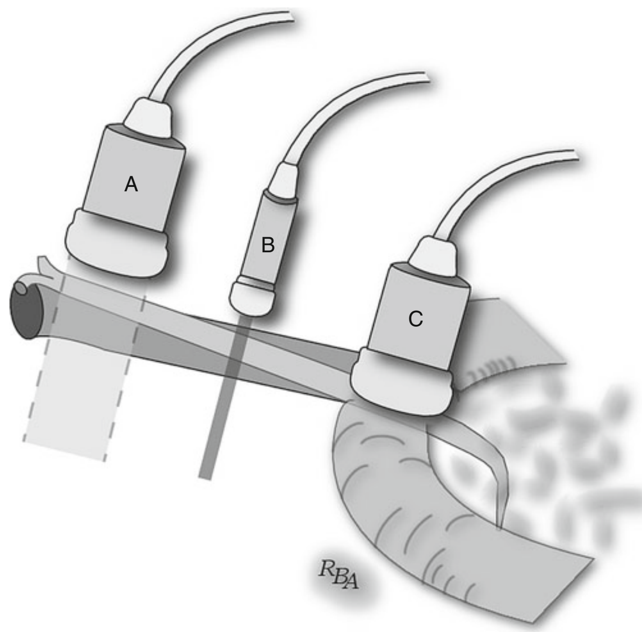

Fig. 4.29 (*A*) Longitudinal scanning of the bile duct during laparotomy. (*B*) Transverse scanning of the bile duct. (*C*) Compression of the duodenum displaces intraluminal air and allows imaging of the retroduodenal and intrapancreatic portions of the common bile duct

Pancreas Scanning Technique

IOUS of the pancreas can be done either with a side- or an end-viewing probe. Prior to any dissection, the gland can be seen by indirect scanning using the duodenum, stomach, gastrohepatic/gastrocolic ligaments, or the transverse mesocolon as an acoustic window (Fig. 4.31). Once the lesser sac is entered, direct contact scanning on the anterior surface of the gland is done. However, like the extrahepatic bile ducts, the

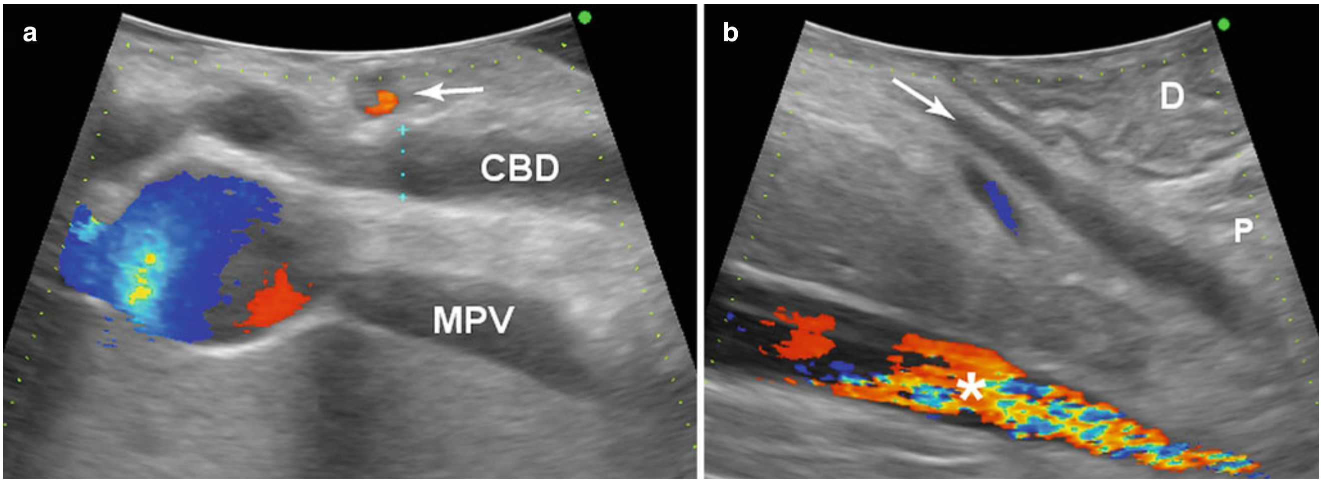

Fig. 4.30 (**a**) Contact scanning of the hepatoduodenal ligament in the longitudinal plane. This patient has aberrant anatomy. There is a right hepatic artery (*white arrow* and a signal on color Doppler) that courses anterior to the common bile duct (*CBD*, no flow signal). The main portal vein (*MPV* and a flow signal) is posterior to the bile duct. (**b**) Compression scanning through the duodenum (*D*) in the longitudinal plane shows the common bile duct (*white arrow*), the superior head of the pancreas (*P*), and the inferior vena cava (* and flow signal)

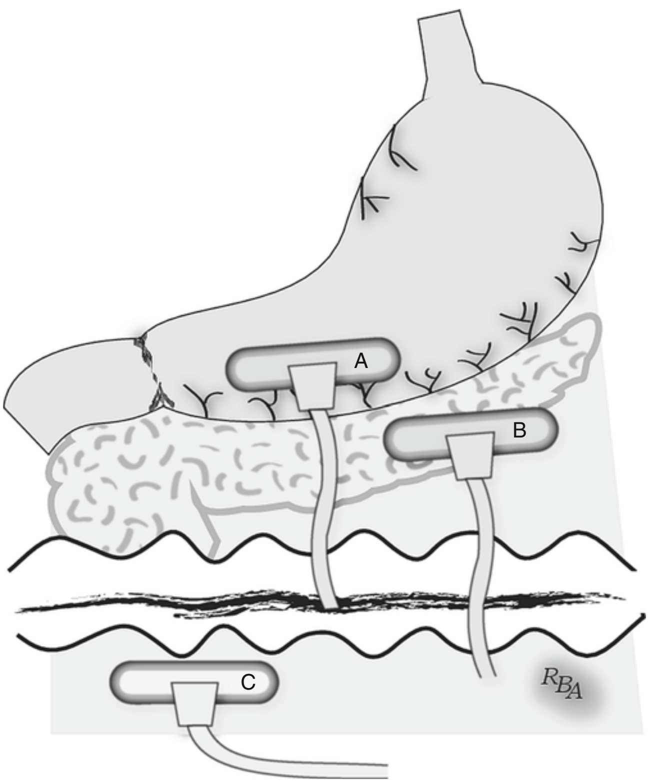

Fig. 4.31 Intraoperative pancreatic scanning. Several acoustic interfaces allow pancreatic imaging without dissection. (*A*) Transgastric. (*B*) Gastrocolic or gastrohepatic ligaments. (*C*) Transverse mesocolon

normal pancreas may be so thin from anterior to posterior that much of the gland immediately beneath the transducer is missed by being in the near field. Consequently, a probe standoff technique often is necessary to examine the entire gland (Fig. 4.32). A saline immersion technique works in most cases if the intent is diagnostic, but if an intervention is planned, a saline-filled glove may be useful to more easily guide a needle for biopsy or duct cannulation, rather than trying to do this while the gland is underwater.

As described for the liver and bile ducts, develop a standardized approach to pancreatic scanning to facilitate complete scanning and employ it every time (Table 4.7). Begin with indirect scanning, followed by direct scanning, if indicated. Longitudinal scanning is most common for the pancreas (Fig. 4.33). The principles are similar to TAUS, much of the pancreatic tissue can be inferred based on identification of surrounding vessels. Find the superior mesenteric or portal vein as it passes posterior to the pancreatic neck and scan the neck, body, and tail of the pancreas (Fig. 4.34). Change the probe to rescan these parts of the gland in the transverse dimension. Repeat these steps after immersing the pancreas in a saline bath. This allows a clear view of superficial structures or a very thin gland that may be lost in the near field during contact scanning. Pay careful attention to the pancreatic duct during the longitudinal portion of the study to identify its relationship to any adjacent lesions (Fig. 4.35). Examine the pancreatic head starting at the portal vein and working toward the patient's right. Much of the approach to scanning the head of the pancreas is similar to that described for examining the distal bile duct in the previous section. Adjacent vessels including the aorta, celiac axis, superior mesenteric artery, gastroduodenal artery, and the corresponding veins are clearly seen; mapping in relationship to masses is easily done with IOUS.

When a mass lesion is present in the pancreas, especially when dealing with neuroendocrine tumors, it is helpful after the initial scan to completely mobilize the gland. This includes Kocher's maneuver and elevating the body/tail out of the retroperitoneum. In this way a combination of

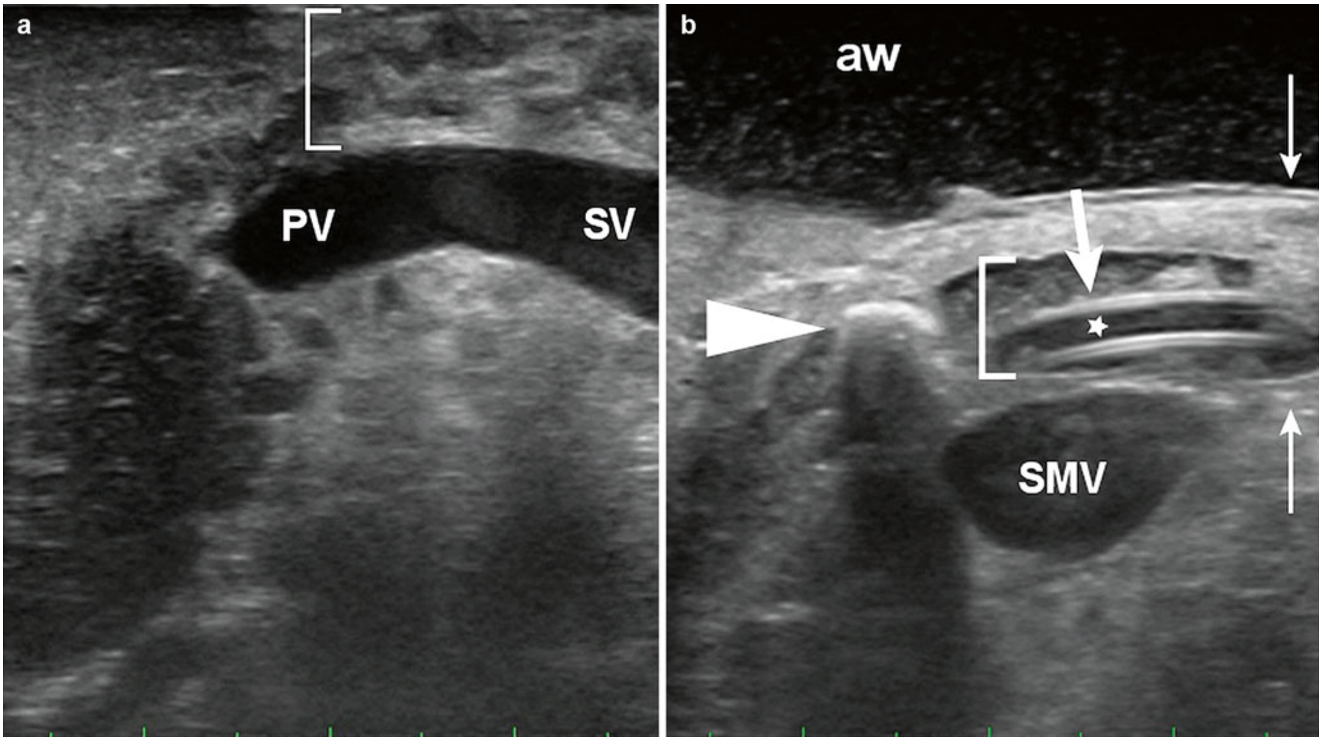

Fig. 4.32 (**a**) Contact scanning shows very little detail in the pancreas due to the thin gland (*white bracket*), which lies anterior to the portal (*PV*) and splenic (*SV*) veins. (**b**) Probe standoff scanning using a saline immersion technique to provide an acoustic window (*aw*) shows the detail missing with contact scanning. This patient has a very dilated pancreatic duct (*white bracket*) due to a pancreatic duct stone (*white arrowhead*) with posterior shadowing. A pancreatic duct stent (*white arrow*, * within the lumen of the stent) is present within the duct. The anterior and posterior surfaces of the gland are shown by the thin white opposing arrows. Superior mesenteric vein (*SMV*)

palpation and IOUS is used to find small tumors. Both contact and standoff scanning may be necessary to identify these small tumors in combination with palpation.

Laparoscopic Ultrasound

Laparoscopic ultrasonography has grown in importance as more procedures have transitioned to a minimally invasive approach. Its use is essential to overcome the lack of tactile feedback during laparoscopic procedures; it supplants the role of palpation that is so important during open surgery to identify specific anatomic structures or mass lesions. LUS can identify critical structures during dissection or screen organs for masses. It is indispensable in guiding resection or ablation procedures during minimally invasive operations since open IOUS or palpation are not feasible.

LUS probes have evolved considerably since their inception. Current probes typically are side-viewing, high-frequency transducers on flexible tip shafts. Most shafts are 10 mm in width allowing introduction through 12 mm trocars. The flexible tip allows much more freedom in scanning areas difficult to reach with the older rigid shaft probes. The relatively long footprint of the current transducers allows imaging of wide areas in an efficient manner. The positions for LUS trocar placement are determined by the type of examination being performed and the organ of interest, as illustrated in the following sections. The most common trocar positions used for LUS are shown in Fig. 4.36.

LUS has many similarities to IOUS in terms of probe placement and manipulation. However, there are some important differences. The first is image display. Placement of the ultrasound machine on one side of the patient or the other is less critical for LUS if a picture-in-picture setup is feasible. If this is not feasible, the ultrasound machine is positioned opposite the surgeon with placement of the ultrasound and laparoscopic monitors next to each other to allow easier coordination of the images. Displaying the ultrasound image on the laparoscopic monitor with both the ultrasound and laparoscopic images visible at the same time facilitates probe movement and LUS image interpretation. This is particularly helpful, allowing one to correlate the probe's position on an organ with the expected ultrasound image, an advantage described earlier that assists in image interpretation. The second difference is probe orientation. The configuration of the transducer on the shaft results in a longitudinal orientation of the probe, and this is often the easiest orientation to obtain images, particularly when a single port in the periumbilical position is used. However, to replicate a similar image to that

Table 4.7 Stepwise approach to pancreas scanning: intraoperative/laparoscopic

Techniques	
	Indirect scan
	Direct scan
	Contact
	Saline immersion probe standoff
	Probe standoff using saline-filled glove if intervention is necessary
Scan pancreatic neck, body, tail	
	Start in longitudinal plane, contact scanning
	Identify portal vein/superior mesenteric vein
	Move probe to the patient's left of the vein to scan neck, body, tail
	Identify pancreatic duct
	Note lesion location, size, and features
	Identify any vascular/duct involvement or thrombosis
	Repeat scan in the transverse plane
Scan pancreatic head	
	Start in longitudinal plane, contact scanning
	Identify portal vein/superior mesenteric vein
	Move probe to the patient's left of the vein to scan head, uncinate
	Identify pancreatic duct
	Note lesion location, size, and features
	Identify any vascular/duct involvement or thrombosis
	Repeat scan in the transverse plane
	Identify retroduodenal bile duct using transduodenal compression scanning
Saline immersion probe standoff scanning	
	Repeat scan using probe standoff to view superficial portions of the gland
Mobilize pancreas	
	Repeat contact and probe standoff scanning after gland mobilization if necessary

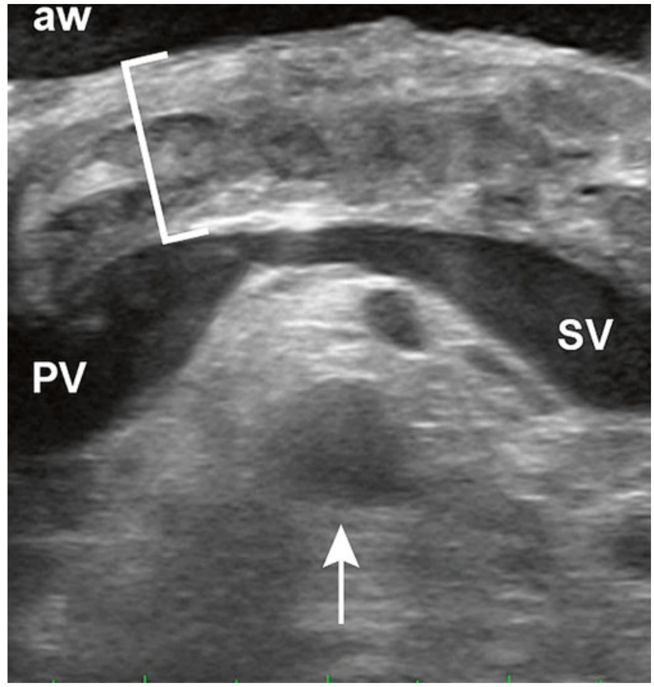

Fig. 4.34 Intraoperative ultrasound of the pancreas. The principles and images are very similar to those for transabdominal pancreatic scanning. The transducer is placed in the longitudinal plane with saline as an acoustic window (*aw*). This gives the prototypical image of the vasculature surrounding the pancreas that facilitates its identification. The pancreas is denoted by the *white bracket*. The pancreas lies just anterior to the portal vein (*PV*) and the splenic vein (*SV*). The superior mesenteric artery (*white arrow*) is seen posterior to the veins

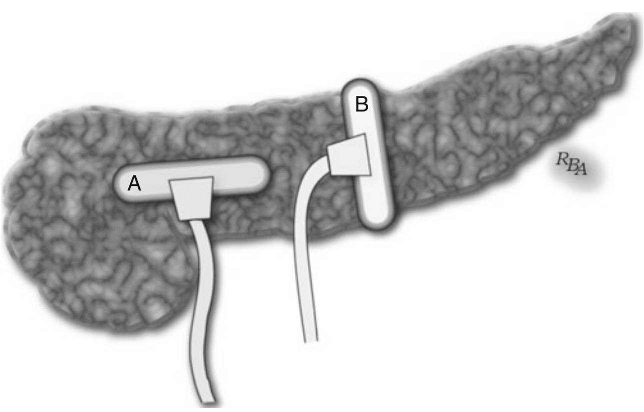

Fig. 4.33 Intraoperative pancreatic scanning. Longitudinal (*A*) and transverse (*B*) scanning of the pancreas

of a side-viewing IOUS probe, which typically is oriented in a transverse position relative to the probe cord, the LUS probe must be oriented likewise (Fig. 4.37a). In addition, because the probe may be changed from one trocar to another to allow complete organ examination, care should be taken to reorient the image display to insure that the image is viewed in the conventional manner (Fig. 4.37b). This may require image inversion, usually an option button on the machine, which changes the orientation of the image display. Finally, because of the probe configuration (longitudinally on a long shaft), transverse image can be challenging when trying to replicate images traditionally seen by IOUS. Therefore, LUS can have a more difficult learning curve since one must often think in longitudinal images rather than transverse, particularly when imaging the liver. This can be disconcerting until sufficient experience and pattern recognition is gained.

LUS probe movements mimic those in open IOUS, but sliding (Fig. 4.38) and tilting (Fig. 4.39) are the most common. More difficult are rotational maneuvers, which make multi-planar scanning of an area of interest more tedious. Rocking the probe by flexing the tip up or down simulates the open technique (Fig. 4.40). Contact and probe standoff scanning techniques are used, but a probe standoff technique may be even more useful in LUS when imaging the superior aspects of the liver or the extrahepatic bile duct. A probe standoff technique may be particularly effective when combined with the rocking movement.

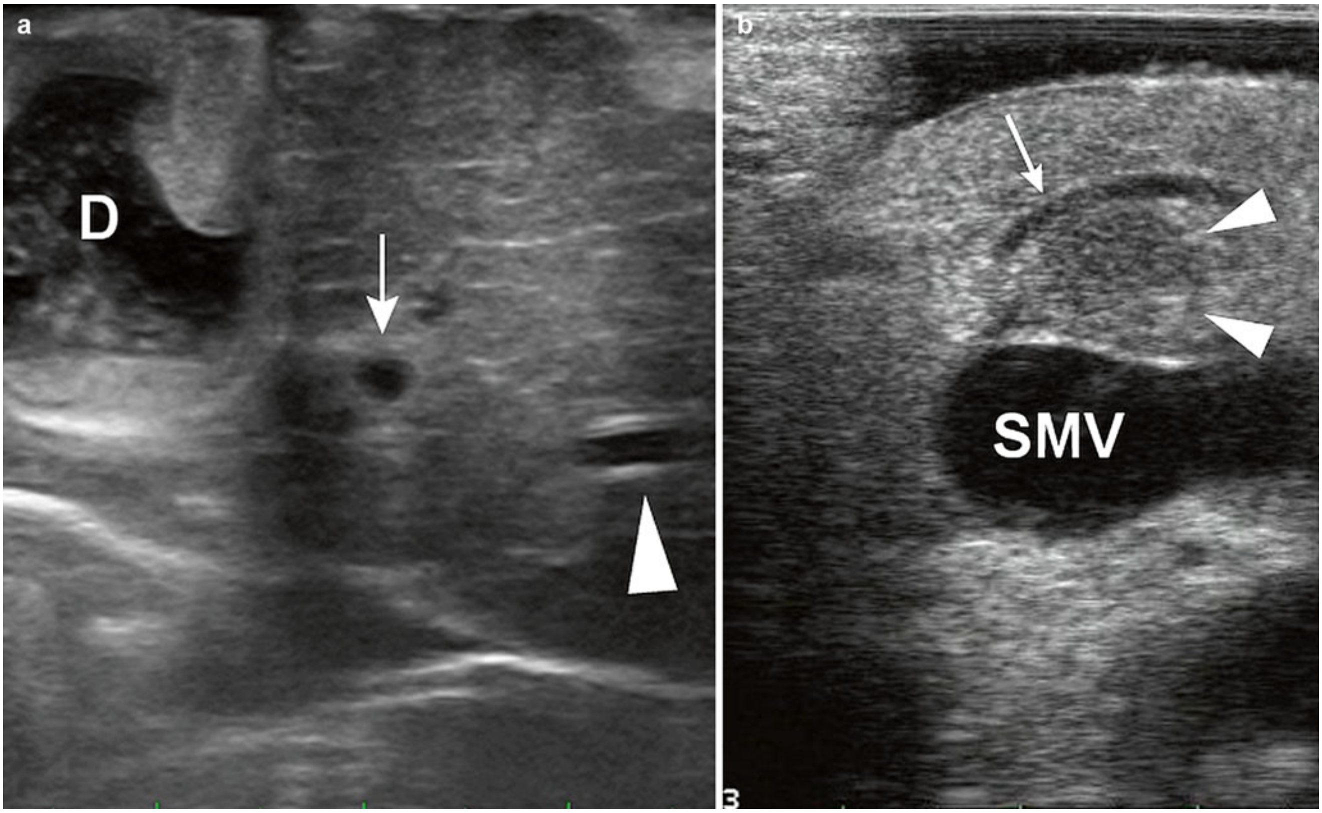

Fig. 4.35 Intraoperative ultrasound, pancreas, longitudinal plane. (**a**) An image through the head of the head of the pancreas shows the duodenum (*D*) just to the right of the pancreatic head. Within the head are a transverse view of the distal common bile duct (*white arrow*) and a longitudinal view of the distal pancreatic duct (*white arrowhead*). (**b**) Longitudinal view at the neck of the pancreas showing the pancreatic duct (*white arrow*) draped over a neuroendocrine tumor (*white arrowheads*). The tumor lies anterior to the superior mesenteric vein (*SMV*)

Liver Scanning Technique

The most useful initial trocar to begin hepatic scanning is one in the right subcostal position. We place a 5 mm trocar initially in the supra-umbilical midline to allow a visual examination of the peritoneal cavity and its contents. Choosing the appropriate distance superior to the umbilicus for trocar placement is based on the patient's body habitus. The simplest way to judge this is to place the tip of the LUS probe approximately at the level of the right nipple and measure the spot where the probe would exit in the midline if it was inserted to its full length. This should allow examination of the superior most portion of the liver when the probe is fully inserted through the trocar. Once the midline trocar is in position and no findings that would preclude the intended procedure are noted, place a right subcostal 12 mm trocar in the line of the intended subcostal incision. Scanning from the right subcostal position offers the closest approximation to a transverse view, although this is more likely to be somewhat oblique in orientation rather than truly transverse. If the liver is not completely visible from this trocar position, the midline trocar is exchanged for a 12 mm one and the LUS probe moved to this position. Remember to reorient the image on the monitor after changing positions. Occasionally, a left subcostal trocar is necessary to allow full examination of the liver. If the falciform ligament impedes probe placement to the other side of the liver, divide a portion of it and pass the probe through to the other side. The choice of which side to place the initial subcostal trocar is determined by the position of the liver as judged from the umbilical port site.

The steps for LUS scanning of the liver are similar to IOUS. A systematic approach is used each time and is the same as that described earlier for IOUS; define the vascular structures, followed by segmental parenchymal scanning. This can be difficult and unsettling, though, to the beginner because the familiar image orientation is more difficult to achieve through the relatively limited mobility allowed by moving a LUS probe through a fixed trocar(s). It is easiest to begin scanning from a trocar placed in the right subcostal position as it affords a view closest to the familiar transverse one (Fig. 4.41a). The transverse images are obtained mainly through sliding movements working from the superior portion of the liver to the inferior edge (Fig. 4.41c, e). The vessels are mapped out using a combination of transverse, oblique, and longitudinal views. Parenchymal scanning is more easily accomplished by scanning in the longitudinal plane

(Fig. 4.41b). With the probe longitudinal on the liver, the shaft is tilted side to side to cover a wide area of parenchyma without moving the probe in relationship to the surface of the liver. Begin parenchymal scanning at the superior border of the liver, tilt (roll) it side to side to view the segment, and then pull the probe toward the inferior edge of the liver and repeat the process (Fig. 4.41d and f). A series of overlapping movements done in this fashion allows complete scanning of the parenchyma. Several areas may pose imaging difficulties: the superior liver, segment 7, and the posterior liver when the liver is enlarged or steatotic. The superior liver is most easily scanned in the longitudinal plane using contact scanning. However, adequate images may require a probe standoff technique to fully view the superior liver and segment 7. When the posterior liver is difficult to see from an anterior position, moving the probe to the inferior liver may give a better view using either a contact or probe standoff technique. For a probe standoff technique, place the patient in the Trendelenburg position and fill the right upper quadrant with saline. As with IOUS, a probe standoff technique facilitates examination of a rough surface or lesions close to the surface of the liver.

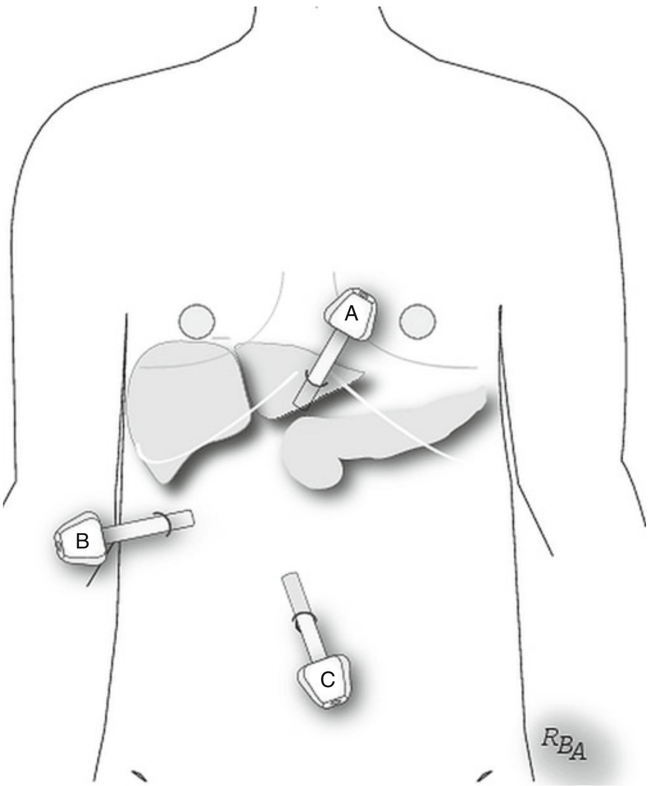

Fig. 4.36 Trocar placement for laparoscopic ultrasonography of upper abdominal organs. Common viewing sites include a subxiphoid port (*A*), a right subcostal port (*B*), and the periumbilical port (*C*)

Biliary Scanning Technique

Optimal biliary scanning is achieved through a two-trocar approach. Scanning is done through the umbilical port and an epigastric/subxiphoid port (Fig. 4.36). Similar to IOUS, LUS of the bile ducts should be done prior to dissection and cholangiography to avoid introducing artifacts. Contact scanning and saline immersion for a probe standoff technique may be necessary to obtain all the necessary images. Color Doppler can be particularly helpful to distinguish vessels from the bile ducts; it should be used liberally during biliary scanning.

Since the laparoscope usually is in the umbilical trocar, begin biliary scanning from the epigastric trocar. This allows transverse scanning of the hepatoduodenal ligament and its

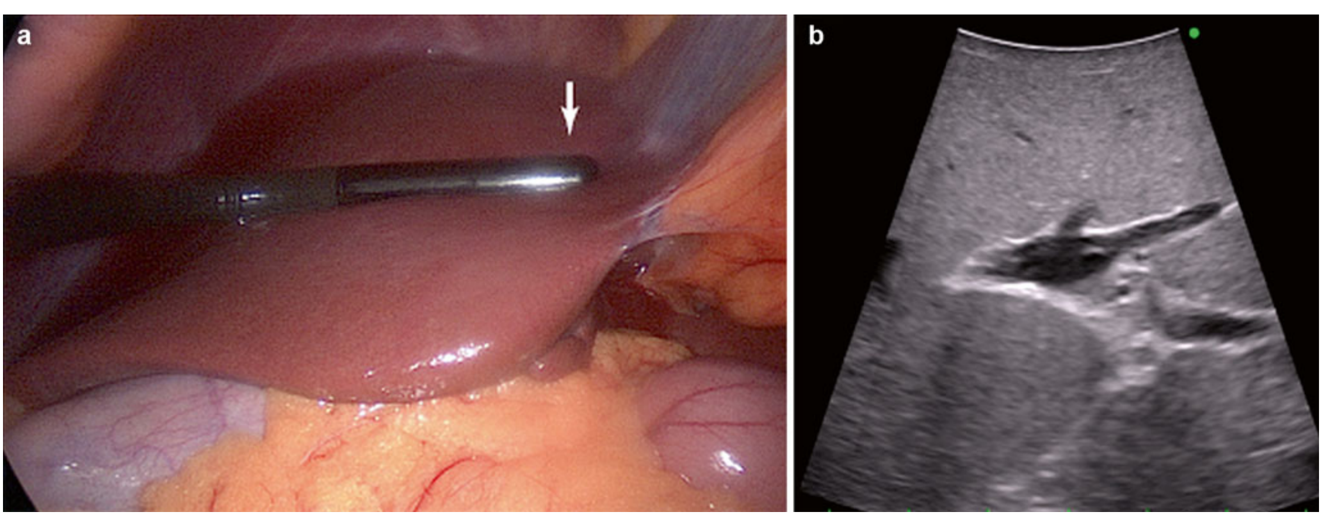

Fig. 4.37 Laparoscopic ultrasound examination of the liver in the transverse plane. (**a**) The probe is placed through the right subcostal port and the tip deflected to orient it transversely. Be sure the tip (*white arrow*) is oriented such that the image on the monitor (**b**) has it on the right side of the screen (*green dot* corresponds to *white arrow* in panel **a**)

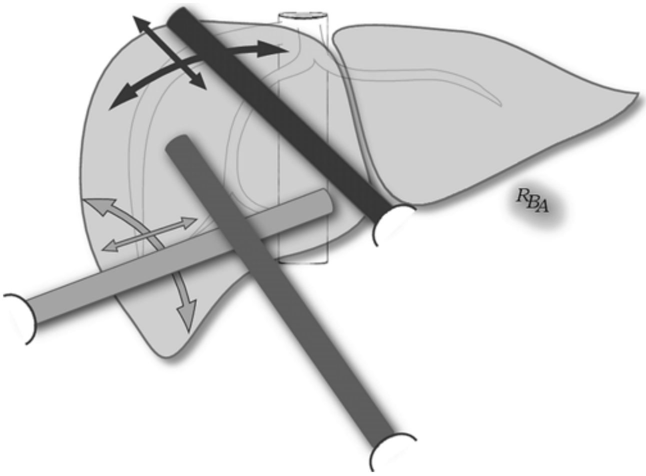

Fig. 4.38 Laparoscopic ultrasound, sliding probe movement for liver scanning. Nearly all the liver can be scanned in the transverse, longitudinal, and oblique planes using a sliding movement through the three standard port sites

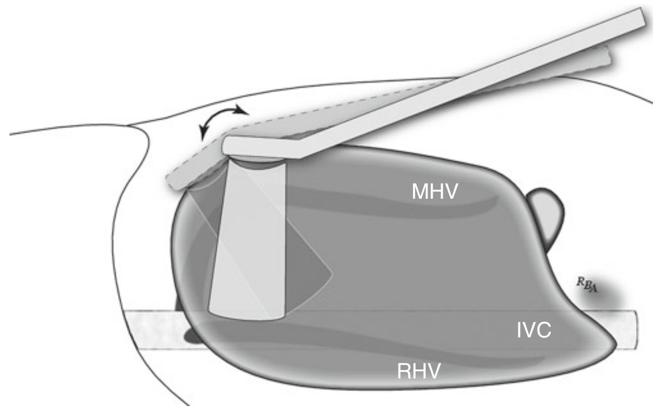

Fig. 4.40 Laparoscopic ultrasound, rocking probe movement for liver scanning. Flexing the tip of the probe up or down simulates the rocking motion of intraoperative ultrasonography. This allows examination of a wide area surrounding a structure of interest using multiple parallel images as the tip is flexed. Tip flexion also allows examination of the superior surface of the liver, something that is very difficult with a rigid probe. *MHV* middle hepatic vein, *RHV* right hepatic vein, *IVC* inferior vena cava

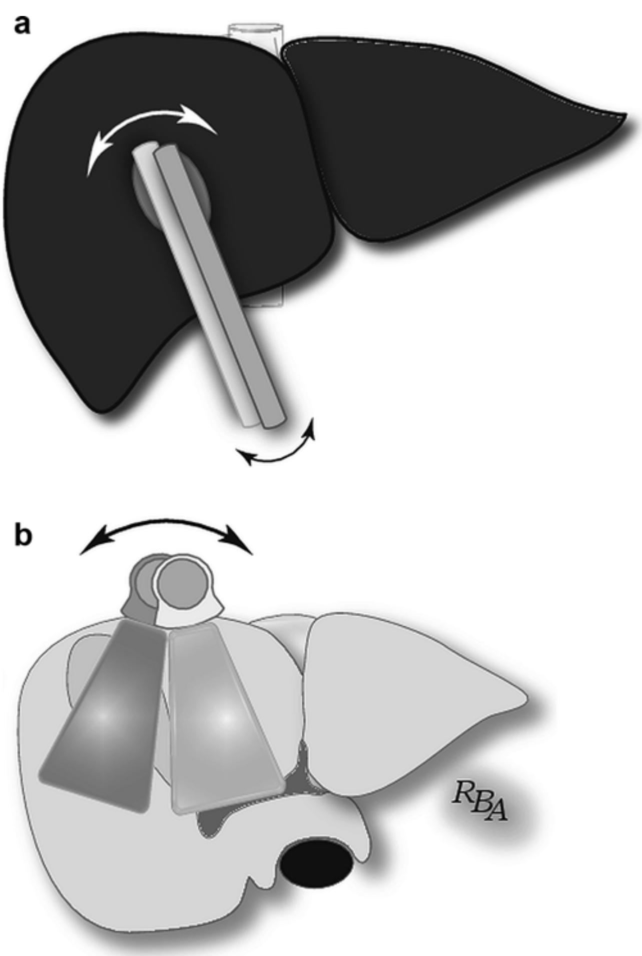

Fig. 4.39 Laparoscopic ultrasound, tilting probe movement for liver scanning. Rotating the ultrasound probe shaft clockwise and counterclockwise tilts the crystal array from side to side and is a very effective technique for scanning large areas of the liver with little movement in relationship to the liver surface. Anterior (**a**) and transverse (**b**) views of probe tilting movement

structures (Figs. 4.42 and 4.43). Grasp the gallbladder and push it cephalad to expose the hepatoduodenal ligament. Scan the gallbladder directly (Fig. 4.43a, b) and slide the probe along the inferior wall of the gallbladder to its junction with the hepatoduodenal ligament (Fig. 4.43c, d). To examine the duct proximal (toward the hilum) to this, rotate the shaft (counterclockwise) so the crystals move toward the hilum. Most, if not all, of the common hepatic duct should be visible with this maneuver. Once this is seen, rotate the shaft back to the neutral position and slide it inferiorly along the lateral side of the hepatoduodenal ligament. If adequate images cannot be obtained with contact scanning, instill saline to allow a probe standoff technique. When scanning directly along the biliary structures, it is important to apply the minimal pressure necessary to achieve coupling. Any pressure more than this will cause collapse of these very pliable structures and render them absent from the image.

As the probe slides from the proximal hepatoduodenal ligament to the inferior end, the structures visible will change. Along the superior portion of the ligament, the common hepatic duct between the right and left hepatic arteries can be seen anterior to the portal vein. As the probe moves inferiorly, the right hepatic artery will be seen passing beneath the common hepatic duct, followed by the characteristic "Mickey Mouse" view with the bile duct and hepatic artery anterior to the portal vein (Fig. 4.43 e, f). Depending on the location of its junction with the common hepatic duct, the cystic duct may be seen sweeping from near the transducer toward the common hepatic duct as the probe is moved inferiorly along the ligament (Fig. 4.43c, d).

After examination of the suprapancreatic portion of the bile duct, shift the focus to the intrapancreatic bile duct. Slide the probe over the duodenum to the anterior pancreatic head

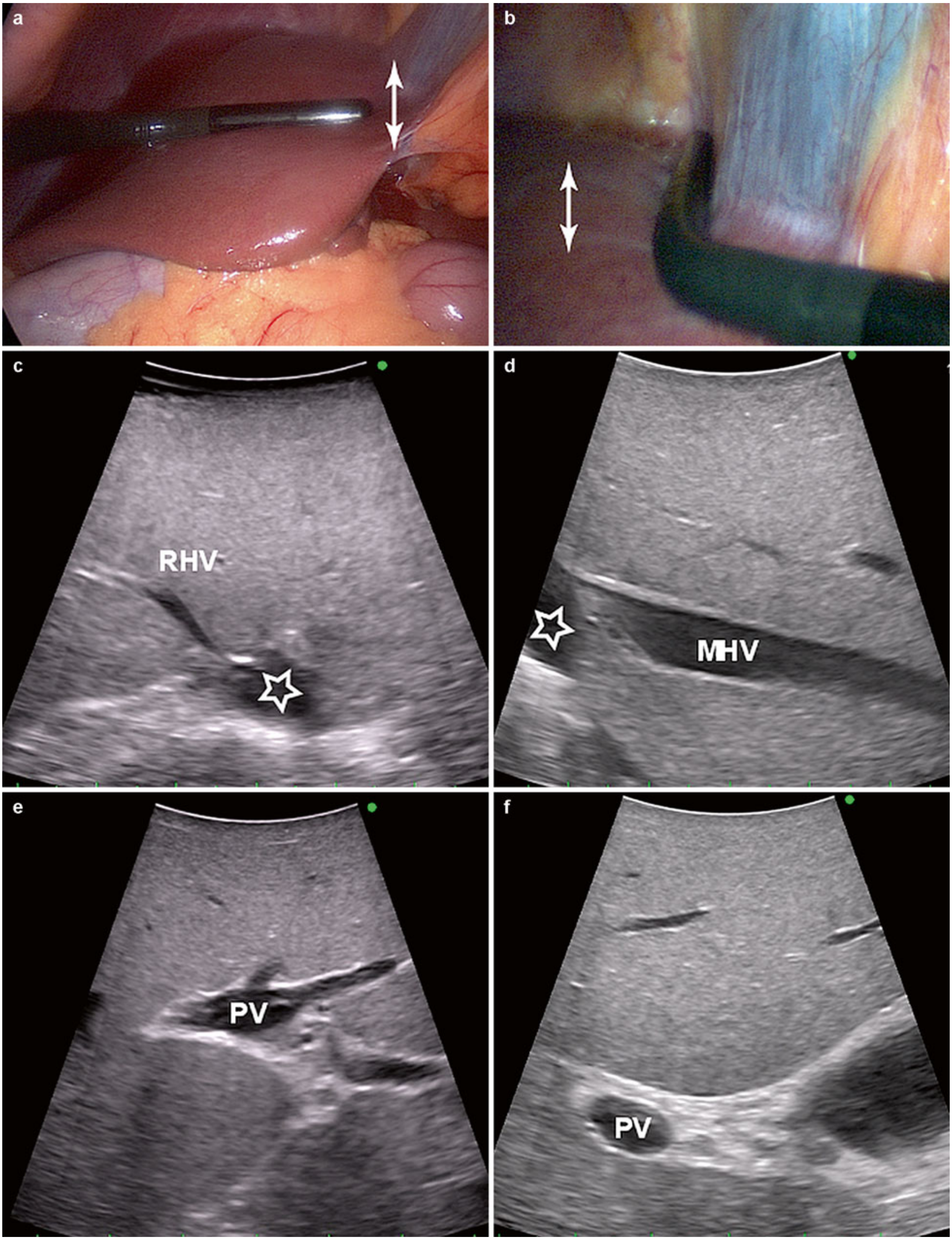

Fig. 4.41 Laparoscopic liver ultrasonography. (**a**) Transverse plane imaging. (**b**) Longitudinal plane imaging. (**c**) Transverse imaging at the superior edge of the liver shows the right hepatic vein (*RHV*) joining the inferior vena cava (*star*). (**d**) Longitudinal imaging at the superior border of the liver shows a longitudinal view of the middle hepatic vein (*MHV*) as it joins the inferior vena cava (*star*). (**e**) Sliding the probe toward the inferior edge of the liver (*white arrow*) while remaining in the transverse plane shows the left portal vein (*PV*) within the umbilical fissure. (**f**) Similarly, sliding the probe inferiorly while remaining in a longitudinal orientation shows the hepatic hilum with the portal vein (*PV*) in cross section

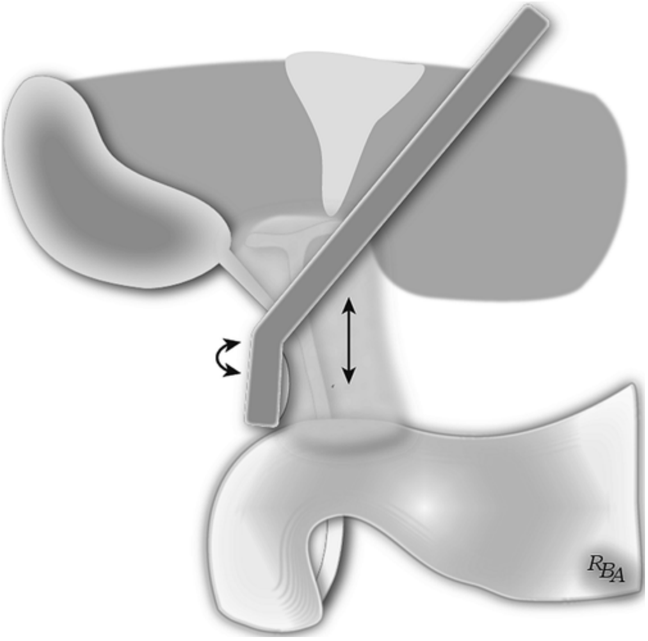

Fig. 4.42 Laparoscopic biliary ultrasonography. Biliary scanning is usually begun through the subxiphoid port. This results in transverse images of the ducts. The ducts are scanned using a combination of sliding (*straight arrow*) and tilting (*curved arrow*). Begin by contact scanning of the gallbladder; slide the probe along the cystic duct to its junction with the hepatoduodenal ligament. The shaft is rotated counterclockwise, tilting the crystal array toward the hilar plate. This images the proximal common hepatic duct. Through a combination of tilting back toward the common bile duct and sliding the probe inferiorly along the hepatoduodenal ligament, most, if not all, of the extrahepatic bile duct can be examined. The retroduodenal and intrapancreatic bile duct can be viewed using duodenal compression as done for the open technique

and scan directly through the head. The bile duct is seen in transverse section from this angle (Fig. 4.43 g, h). The pancreatic duct is seen in the longitudinal plane from this position; often the junction of the bile and pancreatic ducts is seen as the probe slides toward the duodenum (Fig. 4.44a). If the distal bile duct is not well seen, transduodenal compression scanning is the next step. Place the probe on the lateral duodenum and compress the air from the lumen until the pancreatic head and distal bile duct are seen (Fig. 4.44b).

If the common hepatic duct is not visible at the portal plate at the time of the initial examination, repeat the steps outlined above after the tissue in Calot's triangle is dissected free to obtain the critical view. Insert the probe into the triangle and rotate it counterclockwise toward the portal plate to view the proximal hepatic duct.

The second set of bile duct views are obtained through the umbilical port (Fig. 4.45). These show the long axis of the duct and vessels. First examine the gallbladder through the liver; release traction on the gallbladder and place the probe on the anterior hepatic surface over it (Fig. 4.45a, b). Likewise, better images of the proximal right, left, and common bile ducts often are obtained from this trocar using the liver as an acoustic window. After this view is seen, place the probe on the anterior hepatoduodenal ligament to perform direct contact scanning (Fig. 4.45c). Begin with the probe positioned as superiorly on the ligament as possible and then slowly slide it inferiorly to the edge of the duodenum. Prior to sliding the probe, rotate it slightly left and then right to view all the structures in the ligament with minimal probe manipulation. The extrahepatic bile duct, hepatic artery, and

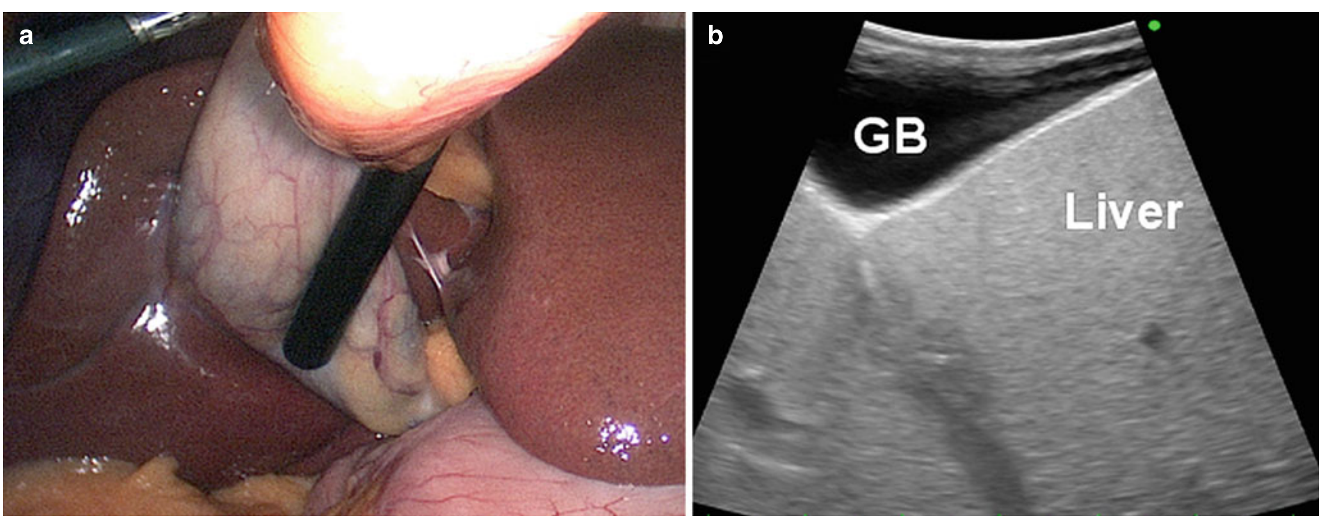

Fig. 4.43 Laparoscopic biliary ultrasonography. Initially, the gallbladder (*GB*) is scanned by direct contact (**a, b**). The probe is slid inferiorly to the cystic duct and its junction with the hepatoduodenal ligament (**c**). This allows viewing of the cystic duct (**d**, *white arrow*). Sliding the probe further inferiorly along the hepatoduodenal ligament (**e**) brings the portal triad into view (**f**) so that the common bile duct (*white arrow*), portal vein (*PV*), and common hepatic artery (*black arrowhead*) are seen ("Mickey Mouse" view). The inferior vena cava (*IVC*) is seen in this image. Finally, transduodenal compression views (**g**, **h**) allow imaging of the intrapancreatic bile duct (*black arrow*). Duodenum (*Du*)

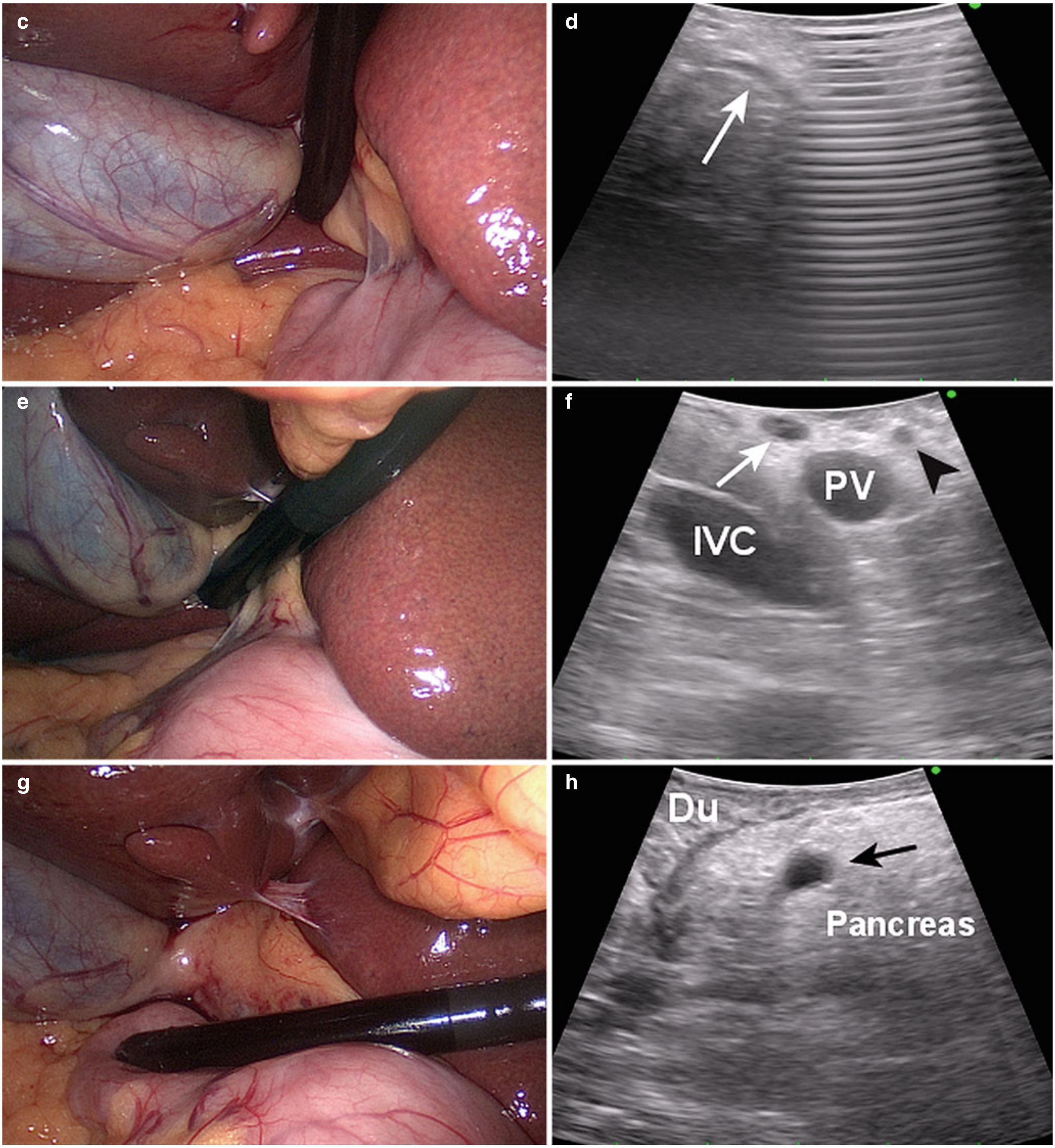

Fig. 4.43 (continued)

portal vein are viewed in their long axis using this approach (Fig. 4.45, image d). The retroduodenal bile duct is seen using a compression technique. Position the probe on the anterior duodenum and slowly compress the probe until the air is displaced from within the lumen (Fig. 4.45, image e and f). The intrapancreatic bile duct and pancreatic duct are seen in this fashion.

Pancreas Scanning Technique

LUS scanning of the pancreas is very similar to that outlined for IOUS. Longitudinal and transverse images are best acquired from right subcostal and periumbilical trocar sites (Fig. 4.46, images a and c). The simplest approach for scanning is a standoff technique using the stomach or gastrohepatic/gastrocolic ligaments as an acoustic interface. For screening purposes, routinely entering the retrogastric space to allow direct contact scanning is unnecessary. Similar to TAUS and IOUS, identification of the surrounding vasculature facilitates recognition of the adjacent pancreas (Fig. 4.47).

Begin the scan through the right subcostal port. Remember to reorient the image on the monitor so that it is shown in the conventional fashion. Proceed in a systematic fashion as outlined for IOUS. Scanning from the right subcostal site allows longitudinal views of the neck, body, and tail (Fig. 4.46b). Scanning toward the patient's right beginning at the portal

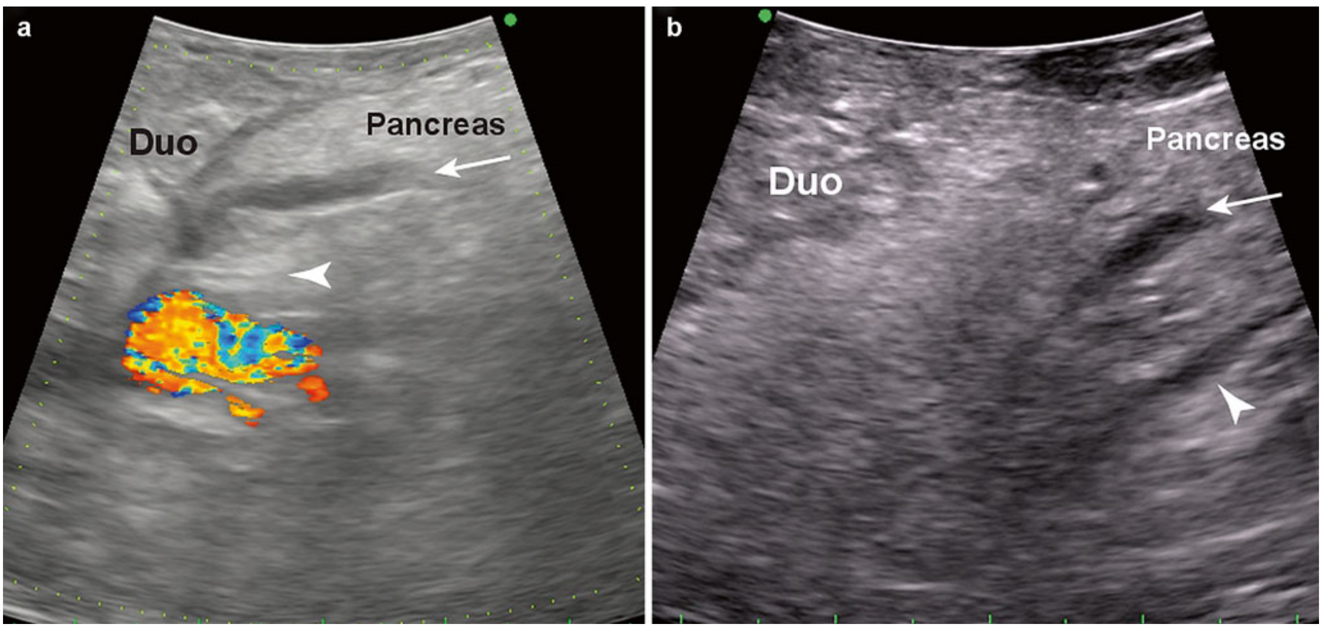

Fig. 4.44 Laparoscopic ultrasonography of the intrapancreatic bile duct and pancreatic duct. (**a**, **b**) Direct scanning through the pancreatic head or duodenal (*Duo*) compression scanning allow a detailed view of the common bile duct (*white arrow*) and the pancreatic duct (*white arrowhead*). Color Doppler shows no flow in the two ducts and a flow signal in the vena cava, directly posterior to the head of the pancreas (**a**)

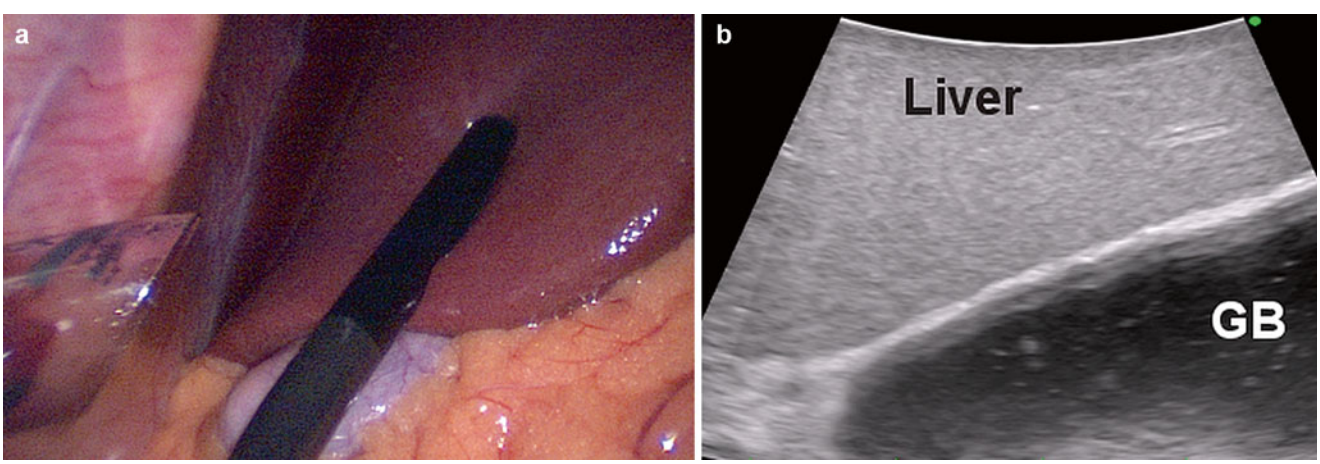

Fig. 4.45 Laparoscopic biliary ultrasonography. In this case, biliary scanning is done through the periumbilical port giving longitudinal views. (**a, b**) Gallbladder (*GB*). (**c**, **d**) Hepatoduodenal ligament with the common bile duct (*CBD*) and portal vein (*PV*). (**e**, **f**) Transduodenal (*Duo*) compression scanning showing the retroduodenal common bile duct (*black arrow*)

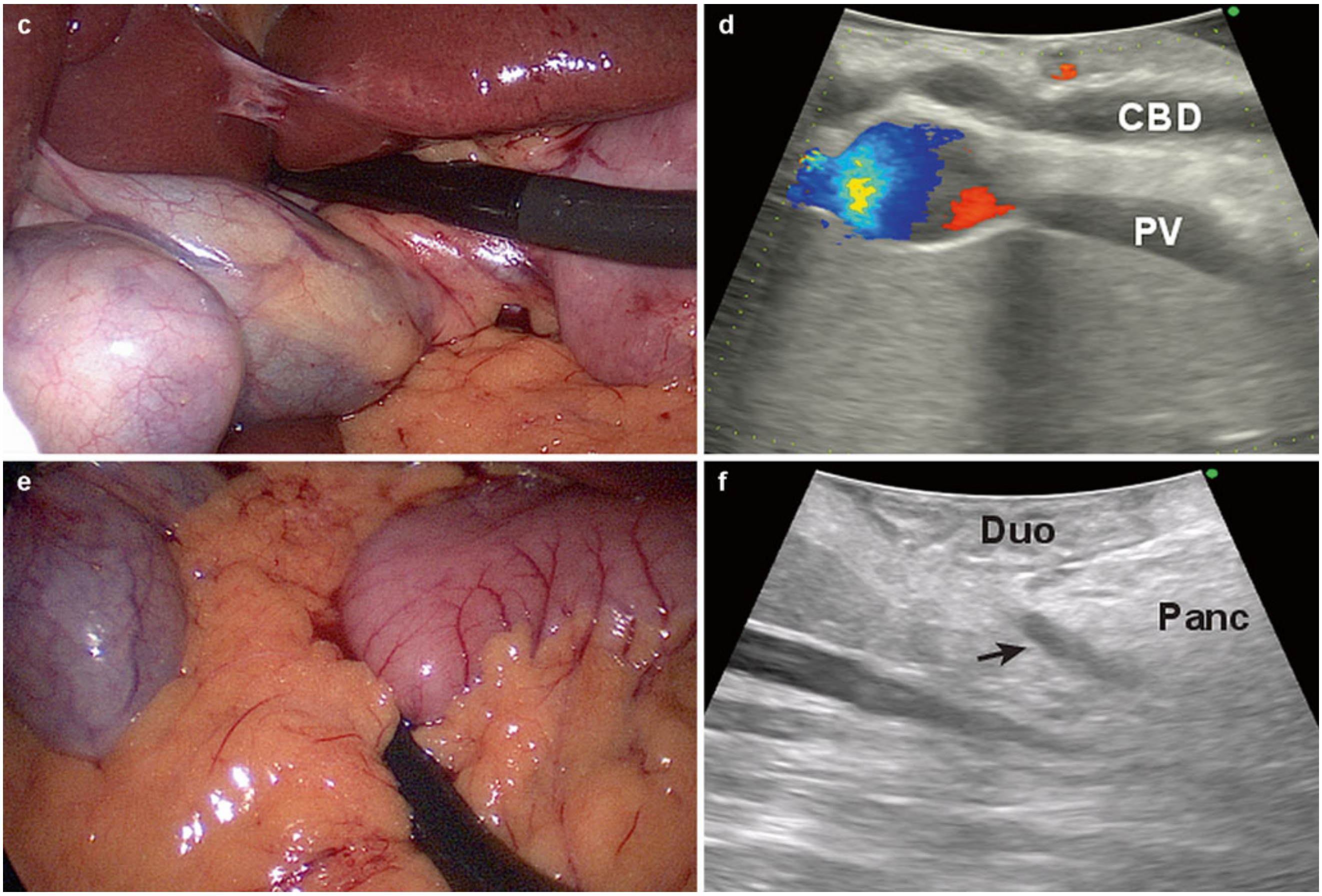

Fig. 4.45 (continued)

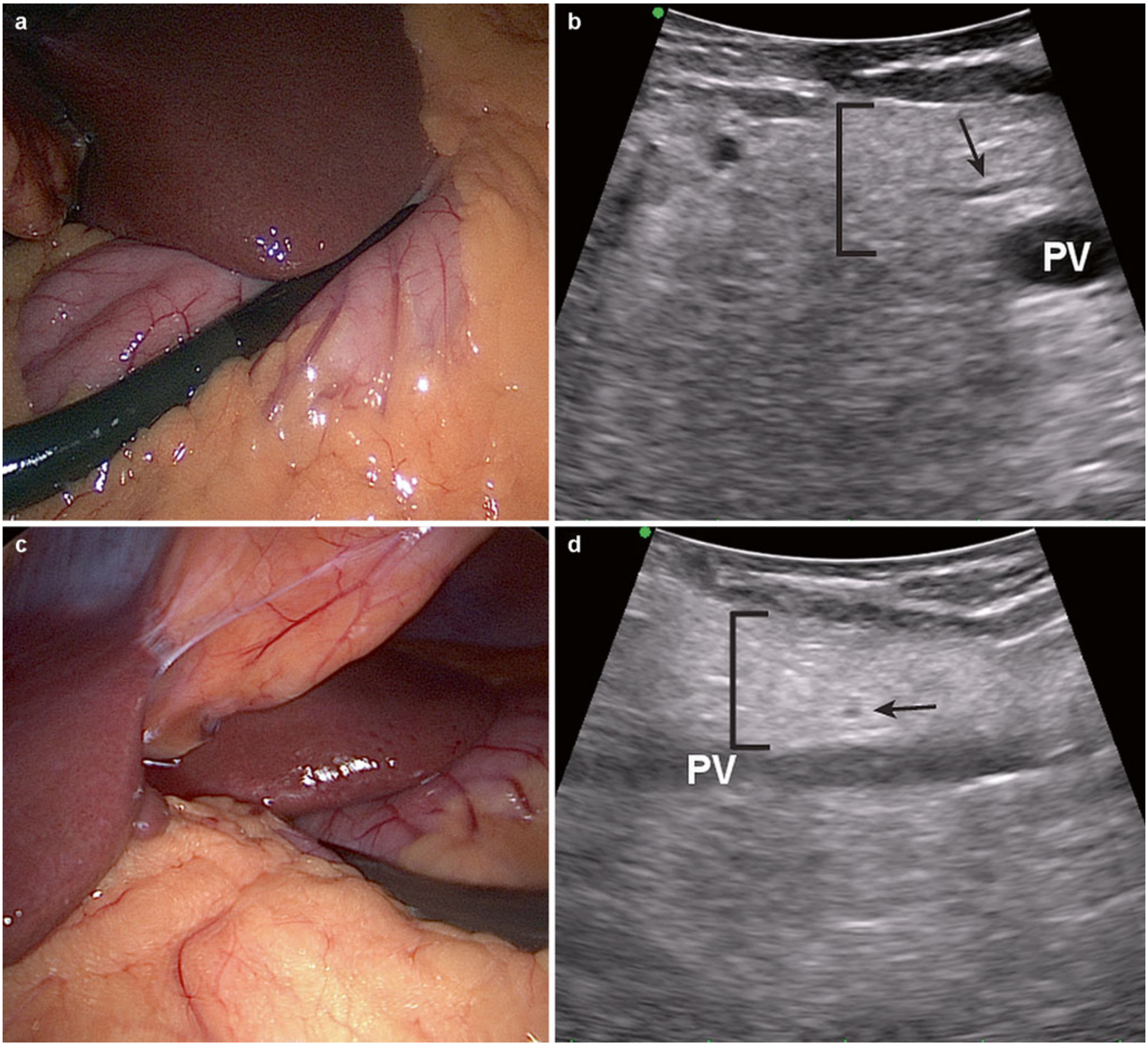

Fig. 4.46 Laparoscopic pancreatic ultrasonography. (**a**) Longitudinal scanning of the pancreas from the right subcostal trocar. A transgastric window is used to view the gland. (**b**) Longitudinal view of the head and neck of the pancreas (*black bracket*). The pancreatic duct is seen (*black arrow*), as well as the portal vein (*PV*). (**c**) Transverse scanning of the pancreas through the periumbilical trocar. Again, a transgastric window is used. (**d**) Transverse view of the neck of the pancreas (*black bracket*) with the pancreatic duct seen in transverse section (*black arrow*). The portal vein (*PV*) is seen in longitudinal section passing posterior to the neck of the pancreas

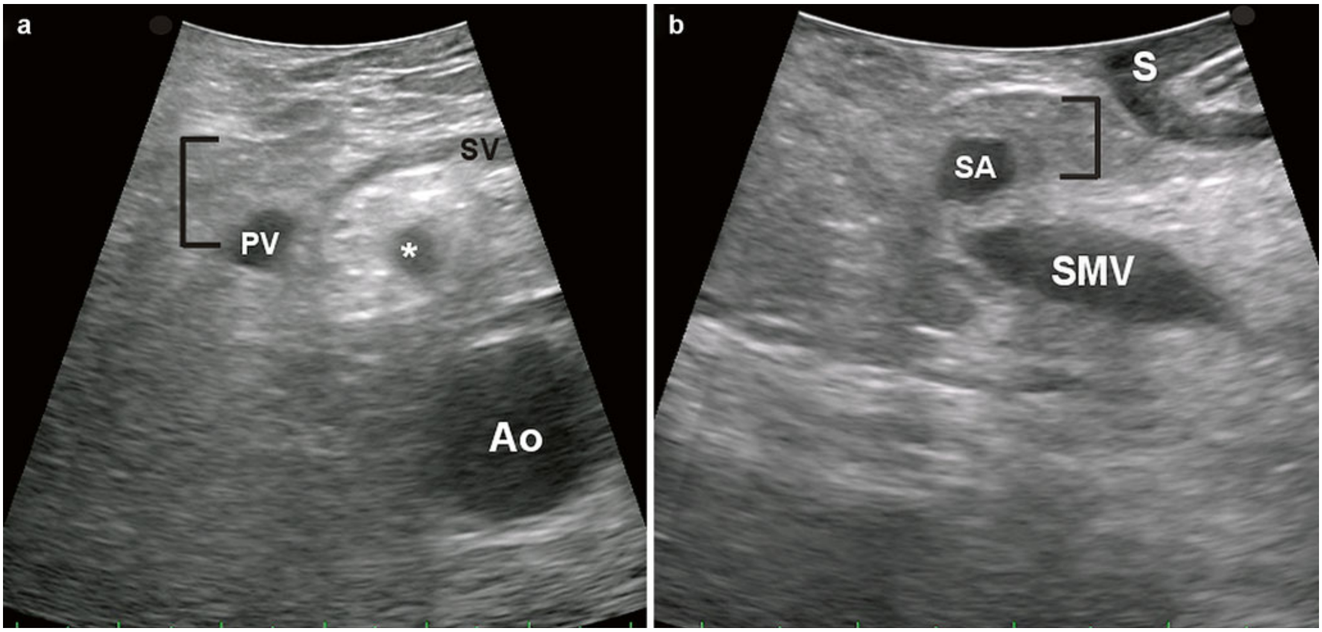

Fig. 4.47 Laparoscopic pancreatic ultrasound. The principles and images are very similar to those for transabdominal and intraoperative pancreatic scanning. (**a**) The transducer is placed in the longitudinal plane using a transgastric window. This gives the prototypical image of the vasculature surrounding the pancreas that facilitates its identification. The pancreas (*black bracket*) lies anterior to the portal vein (*PV*) and the splenic vein (*SV*). The superior mesenteric artery (*white* *) is seen posterior to the veins. The aorta (*Ao*) is posterior to the superior mesenteric artery. (**b**) Transverse position of the transducer using a transgastric (*S*) window. The pancreatic neck (*black bracket*) is seen with the splenic artery (*SA*) running along its anterior border, while the superior mesenteric vein (*SMV*) passes posterior to the neck of the pancreas

vein allows longitudinal examination of the pancreatic head. Moving the probe to the umbilical port permits examination of the gland in the transverse plane (Fig. 4.46d). If examination of the pancreatic head is inadequate, saline immersion and a probe standoff technique may provide better views of the head and uncinate of the pancreas. Again, subtle rotation of the probe clockwise and counterclockwise allows imaging of the entire gland with minimal probe manipulation.

Summary

TAUS, IOUS, and LUS all are effective for gathering additional information during a clinical examination, a procedure, or an operation. While there are differences in the probes and their placement between the approaches, the general principles are very similar. The most important aspect of hepatobiliary and pancreatic ultrasonography is developing a standardized approach and using it for every examination. This leads to readily recognizable images that help the novice gain experience and prevent the experienced sonographer from missing essential information.

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